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U.S. Department
of Transportation
Federal Highway Administration

Demonstration Projects
Program

Demonstration Project No. 54

Sulfur Extended Asphalt

Kennebec County, Maine

ORIGINAL

COMPLETED

90

FHWA-DP-54-2

Initial Report

July 1982

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SULFUR EXTENDED ASPHALT (SEA)
Design and Construction Report

Materials and Research Division
Technical Paper 82-3

Demonstration Project 54
Project 999(582)
February, 1982

Prepared by:

A. E. Gross

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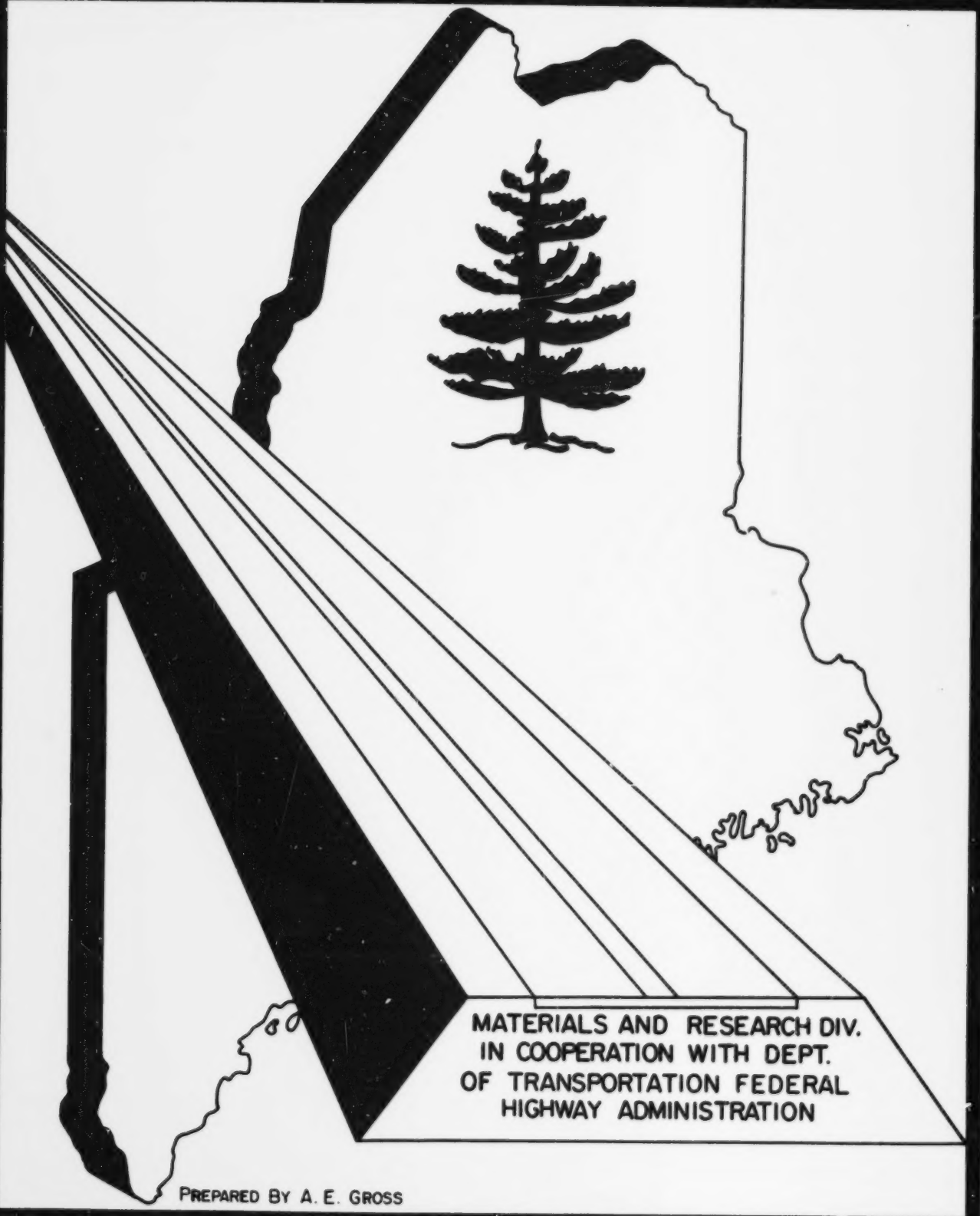

MATERIALS AND RESEARCH DIV.
IN COOPERATION WITH DEPT.
OF TRANSPORTATION FEDERAL
HIGHWAY ADMINISTRATION

PREPARED BY A. E. GROSS

SULFUR EXTENDED ASPHALT (SEA)
DESIGN AND CONSTRUCTION REPORT

MATERIALS AND RESEARCH DIVISION TECHNICAL PAPER 82-3 FEBRUARY, 1982

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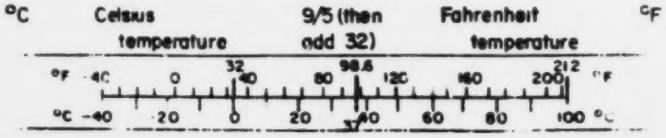
METRIC CONVERSION FACTORS

APPROXIMATE CONVERSIONS FROM METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.6	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
MASS (weight)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons(2000 lb)	0.9	tonnes	t
VOLUME				
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
AREA				
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares(10,000 m^2)	2.5	acres	
MASS (weight)				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
VOLUME				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
TEMPERATURE (exact)				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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ABSTRACT

In 1981 an overlay consisting of sulfur extended asphalt (SEA) pavement was placed on the I-95 interstate system in Maine. Approximately 26,200 tons of the experimental pavement was used. Three different blend weights, 30/70, 20/80 and 10/90 of sulfur to asphalt, were incorporated in the project. The SEA pavement was mixed by the "Direct Method", first adding asphalt then sulfur, using an 8,000 pound batch plant.

This report discusses the design, placement and preliminary evaluation of the pavement. Initial data on frictional characteristics, rideability and strength was also obtained.

The SEA mix was found to produce low concentrations of Hydrogen Sulfide (H_2S) and Sulfur Dioxide (SO_2) and high concentrations of total suspended particulates (TSP) around the paver during the laydown operation.

INTRODUCTION

Shortages and rapidly escalating crude oil costs have impacted pavement maintenance and construction programs. Refineries can economically refine a greater portion of the crude oil residual leaving a smaller portion of asphalt cement (AC). This may explain petroleum product prices escalating about 600 percent while asphalt cement prices have increased over 1,000 percent.

Because of the uncertain supply of asphalt cements for binders, it is necessary to consider other binding agents such as sulfur, to maintain and restore the multimillion-mile highway network. Future supplies of sulfur should exceed the agricultural and chemical demands because vast quantities of sulfur are being removed from sour gas, coalfired plant stack emissions, and through coal liquification in addition to the sulfur obtained from the salt domes by the Frasch Process and mined sulfur.

Successful field trials have been conducted utilizing sulfur as an extender for asphalt cements in portions of the United States, Canada, and Europe. In 1979, the State of Maine placed 3,000 tons of a 30/70 weight blend SEA pavement on the newly constructed southbound lane of I-95 Interstate in the towns of Crystal and Sherman, County of Aroostook. The blending of sulfur and asphalt was accomplished by using the "Direct Method" of adding asphalt, then liquid sulfur, one after the other into the asphalt weigh bucket. Then the combined SEA mixture was dumped into the pug mill of an 8,000 pound batch plant and given about a 40-second wet mix cycle. This procedure was considered successful.

Further research regarding SEA pavements was considered advisable; therefore, in the fall of 1980, Maine DOT entered into Work Order DTFH71-80-54-ME-02 with the Demonstration Projects Division of the Federal Highway Administration (FHWA) to place 25,000 tons of an SEA pavement at a 30/70 weight blend. After

conducting studies of various SEA weight blends, it was decided to expand the original 30/70 weight blend to encompass additional combinations.

Laboratory test results of three weight blends of sulfur and asphalt cement (30/70, 20/80, and 10/90) indicated that the best physical characteristics could be obtained with the smallest addition of sulfur. Also, a paper presented at the 1979 Utah Bituminous Conference indicated 3-7 percent by weight addition of sulfur to asphalt cement greatly improved cold weather ductility characteristics. After reviewing other reports and analyzing the test results of different SEA ratios, it was decided that SEA weight blends of 30/70, 20/80, and 10/90 should be used in the experimental project.

It was also believed that small sulfur additions could eventually be considered as an additive on a regular basis providing the environmental problems associated with sulfur would be proportionally reduced.

The project Change Order and Supplemental Specifications regarding the SEA placement are in Appendix A.

SCOPE

This report contains data pertaining to the design, mixing, placement, and the environmental impact of experimental pavements containing different weight blends of sulfur extended asphalt. Data obtained before and during construction along with follow up surveys will be used to evaluate the performance of the sulfur modified binding agents in comparison with the regular paving grade asphalt used on the same project.

PROJECT DESCRIPTION

There are several distinct areas relative to the overall description of the project. These areas are discussed individually for clarity.

Project Location

The different weight ratios of SEA experimental pavements were placed on the southbound and northbound lanes of the I-95-7(84) Benton-Palmyra interstate project. The climate in this section of the State is moderately severe with a mean Freezing Index of approximately 1,000, as shown in Figure 1.

These experimental SEA pavement sections were incorporated into the major paving project, which extended from the Kennebec River in through Clinton and Burnham ending at the Johnson Flat Road in the town of Pittsfield for a total distance of about ten miles. Both the northbound and southbound interstate lanes were overlayed. The total effective pavement length for pavement evaluation was about twenty miles. The majority of the SEA pavement tonnage was placed on the southbound lane with the remainder on the northbound lane. The project extremities are shown in Figure 2.

Commencing at the northern terminus, Johnson Flat Road Overpass, on the southbound lane, the full depth 10/90 SEA pavement continued southerly for a distance of 1.27 miles; the 10/90 SEA binder with regular AC-10 wearing course continued southerly for 4.55 miles to the Hinkley Road Intersection and continued northerly for approximately 1.27 miles to the Johnson Flat Road Overpass.

Figure 3 shows the plan view of the relative locations of the SEA pavements.

Typical Section

The original roadway section was constructed in 1965, as depicted in Figure 4, with 10 inches of granular borrow, 18 inches of gravel base, 9 inches of crushed gravel, 5 inches of macadam base, and 3 inches of bituminous concrete surface. In 1969 this section was overlayed with a 3/4 inch "H" mix.

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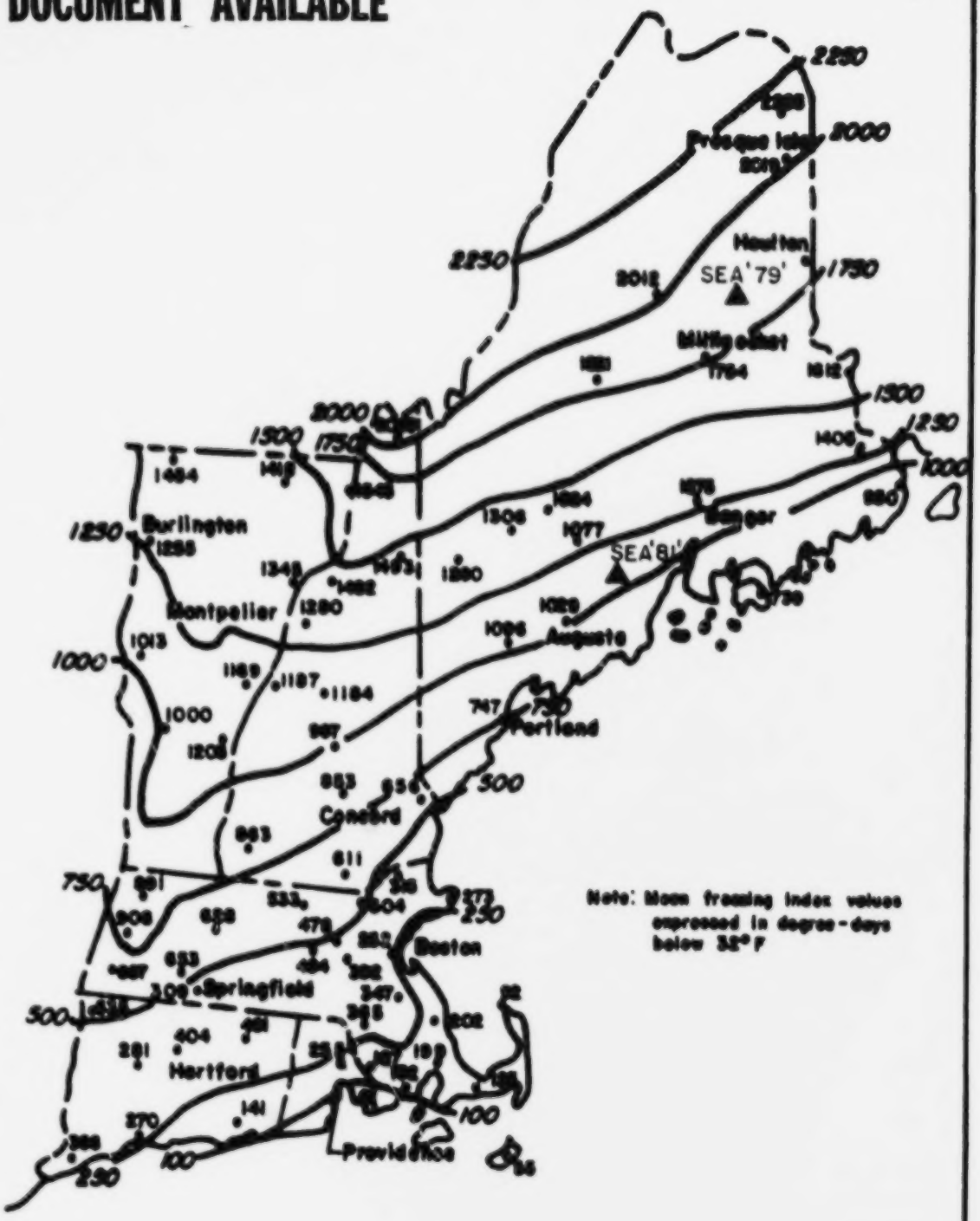

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MISCELLANEOUS PAPER XX

Figure 1 DISTRIBUTION OF MEAN FREEZING INDEX VALUES IN NEW ENGLAND

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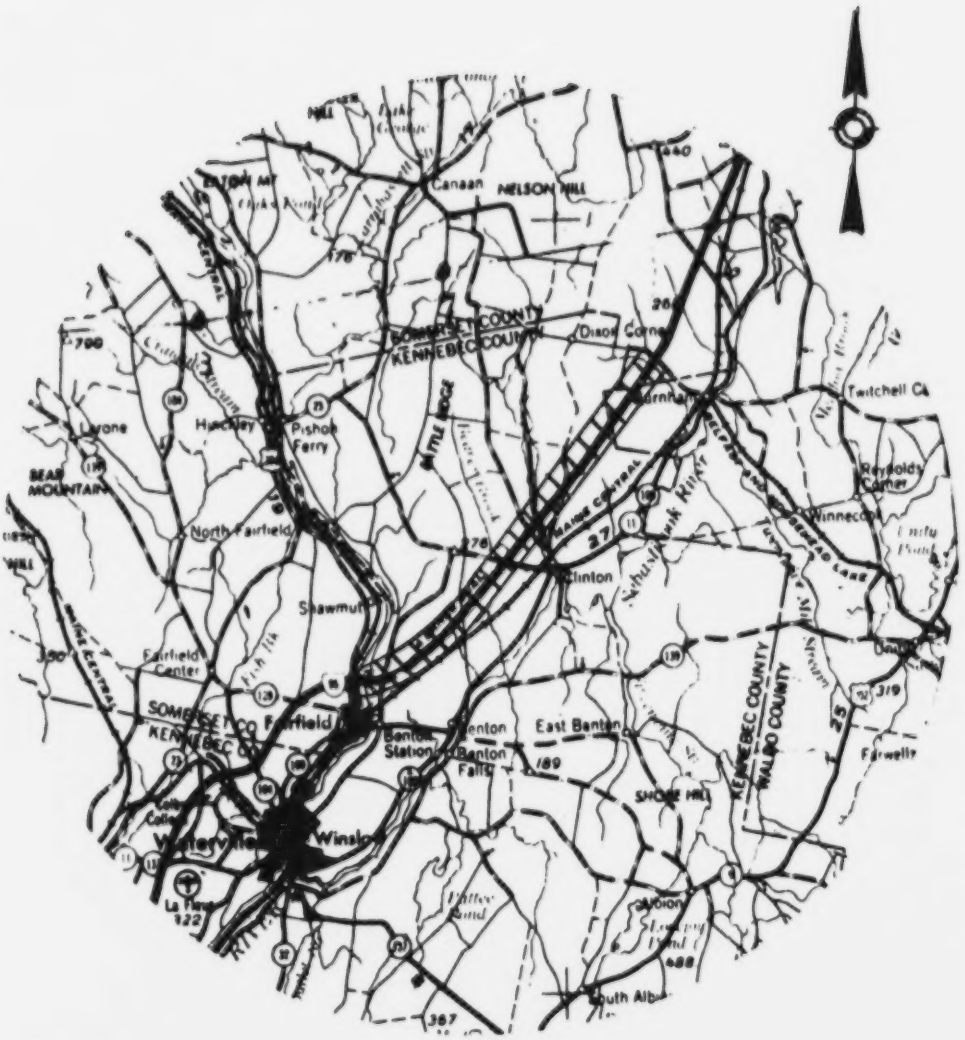

Showing: Location of Project, Towns of Benton, Clinton, Burnham, Pittsfield, Kennebec and Somerset Counties, State of Maine

Figure 2 Vicinity Map, SEA Experimental Project

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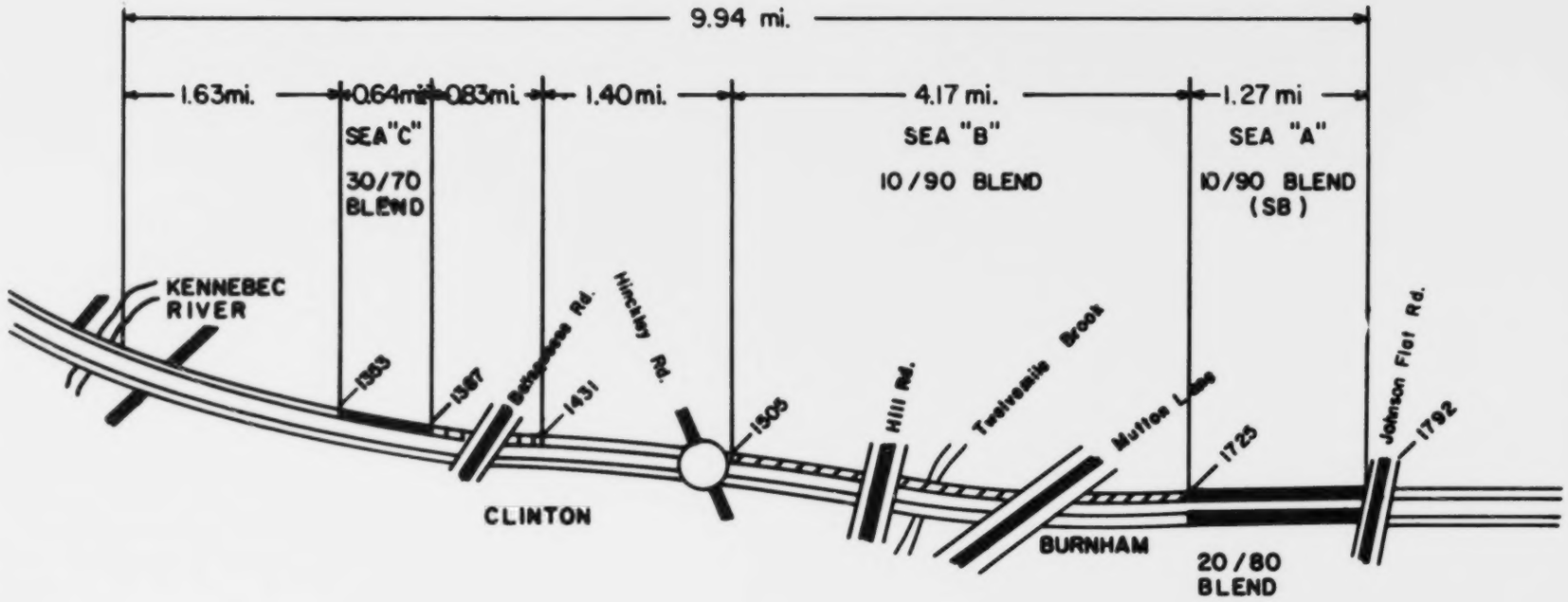


Figure 3 Plan View – Experimental Project

EST. SEA PAVEMENT TOTALS			
SECTION "A"	(NB & SB)	10891	TONS
SECTION "B"	(SB)	11495	TONS
SECTION "C"	(SB)	2763	TONS
	TOTAL	25149	TONS

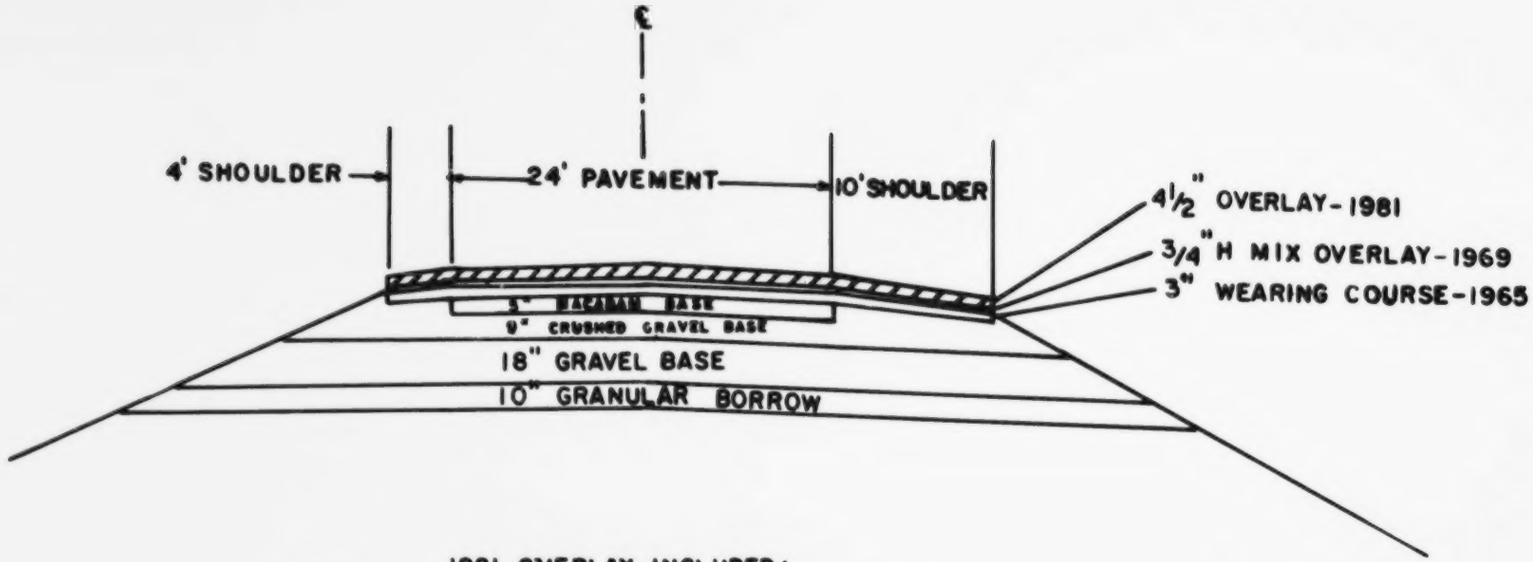
LEGEND

- CONTROL
- SEA – FULL
- SEA BINDER ONLY

DEMONSTRATION PROJECT 54 – SULFUR EXTENDED ASPHALT
WORK ORDER DTFH – 71–80–54 ME–02
STATE PROJECT 999(582)

7

Figure 4 Typical Cross Section



1981 OVERLAY INCLUDED:
1¼" 'C' MIX-WEARING COURSE
2¼" 'B' MIX-BINDER COURSE
½" STONE CHIP-SEPERATER COURSE
½" 'D' MIX-LEVELING COURSE

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The section had deteriorated to a degree that it was considered necessary to overlay the pavement with 1/2 inch of "D" mix level course, a chip seal course-separator, 2 1/4 inch "B" mix binder course, and a 1 1/4 inch wearing course. The sulfur modified binding agent was used only in the top two layers.

Traffic Data

Traffic information obtained in the vicinity of the Hinkley Interchange indicated an Average Daily Traffic (ADT) of 10,728. The northbound lane ADT was slightly higher (5,558) than the southbound lane. The truck traffic was reported to be about 15.5 percent. At the present traffic flow, it would take approximately 16 years to subject the pavement to five million 18-kip (8172Kg) equivalent axle loads.

METHODOLOGY

The Benton-Palmyra field trial represents the first SEA demonstration project conducted by the Maine Department of Transportation. This project was a pavement overlay, whereas the first SEA research pavement was incorporated in a newly constructed interstate project. Both projects were constructed by the "Direct Method" of blending sulfur and asphalt, by the same contractor, and with the same 8,000 pound batch plant.

The Benton-Palmyra project was originally scheduled to include the placement of 25,000 tons of SEA pavement with a 30/70 weight blend of sulfur and asphalt but interim evaluation of the physical characteristics of different SEA weight blends by the department and other agencies caused the investigators to change to three different SEA blends for the project. The reason for the change was the MeDOT found that a significant improvement in binder characteristics could be obtained with less than 30 percent sulfur content. Phillips

Petroleum found that they had to add a small percentage of sulfur to their asphalt cement to meet one State's specification for low temperature ductility. This change actually gave the evaluators an opportunity to compare how different SEA blends resisted reflective cracking.

Preliminary Field Survey

Before any mixture design was initiated, a field survey was conducted to map the cracks in 500 foot test sections within each of the experimental SEA pavement sections as shown by Photos 1 through 3 in the Appendix B.

The pavement condition was noted with all the major cracks being recorded. Prior to the placement of the overlay, other data were obtained which included pavement deflection with a Benkelman Beam, rideability with a Mays meter and frictional resistance with a friction trailer.

Materials

Aggregates

The coarse aggregates for the project were obtained from several sources which included the Bulmer Pit located in Smithfield, the Grover Pit in Canaan, and the Farrin Pit in Norridgewock. The crusher reject sand was obtained from the same sources while the blend sand was obtained from the Maheaw Pit in Clinton. The stockpile gradations of the materials used on the project are shown in Table I.

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TABLE I STOCKPILE GRADATIONS

Sieve Size	3/4"	1/2"	Crusher Reject Sand 1	Crusher Reject Sand 2	Blend Sand
1"	100	100	100	100	100
3/4	93	100	100	100	100
1/2	20	92	100	100	100
3/8	4	37	100	100	100
#4	2	6	91	92	100
#8	1	3	81	81	100
#16	1	2	64	53	98
#30	1	1	41	24	90
#50	1	1	17	12	70
#100	1	1	11	6	38
#200	1	1	6	4	11

The physical characteristics of the aggregates were obtained in the Materials and Research Division's Aggregate Laboratory. The analysis of material included the specific gravity, absorption, fractured faces, elongated particles (5:1), and the quantity of deleterious material. The results of this testing are listed in Table II.

TABLE II PHYSICAL CHARACTERISTICS, AGGREGATES

Test	Percent		Sand
	Coarse Aggregate	Fine Aggregate	
Deleterious	0	0	----
Absorption	1.12	1.03	0.91
Fractured	82.5	81.7	----
Elongated	0.8	1.7	----
Specific Gravity	2.69	2.70	2.67

Sulfur

The sulfur, which was recovered from the Irving Oil Petroleum Refinery at St. John, New Brunswick, was transported to the Benton Plant in insulated

trailers owned and operated by Irving Oil. The sulfur was loaded at the refinery, at a temperature of 310°F which dropped about 20°F during the four hour haul to the project. An oil fired steam "jennie" was used to maintain the sulfur temperature during the batching operation. The sulfur specifications are depicted in Table III and potential sources in the northeast are tabulated in Appendix C.

TABLE III SULFUR SPECIFICATIONS

Purity	99.5% min.
Ash Content	100 ppm max.
Hydrocarbons	100 ppm max.
Arsenic	0.25 ppm max.
Selenium	2 ppm max.
Color	Bright yellow
Temp. (liquid phase)	250°F min. 300°F max.

Asphalt

The AC-10 asphalt cement used as the binding agent was obtained through Koch Asphalt in South Portland, Maine. It was desired that the entire project be completed from the same source of material but because of demands from other areas; Koch was required to change to another asphalt supplier midway into the project.

The AC-10 asphalt cement was a paving grade material which met the State of Maine Specifications[4] as represented by the supplier's Certificates No. 2 and 4 in Table IV.

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TABLE IV ASPHALT SPECIFICATIONS AND CERTIFIED RESULTS

	AC-10 Asphalt Cement		
	Maine Specifications	AC[(K)2] 4/23/81	AC[(K)4] 6/25/81
Specific Gravity	N.R.	1.017	1.031
Viscosity, 140°F (Poises)	1000 ± 200	1109	1045
Viscosity, 275°F (Cs)	250+	335	356
Penetration 77°F, 100g, 5 sec.	80+	123	106
Flash Point	426+	596	650
Solubility in Trichloroethylene	99.0+	99.99	99.81
TFOT: Weight Loss	0.5-	-0.1619	+0.0644
Ductility	75+	150+	100+
Viscosity, 140°F (Poises)	4000-	2747	2199

An independent laboratory determined that the residual sulfur content of the first (K2) shipment of asphalt was 2.86 percent and the second (K4) shipment of asphalt was 4.54 percent.

Mix Designs

From the last week of April through the first week in May the contractor submitted mix design requests, which included 30/70, 20/80, 10/90 SEA weight blends plus the control, for the binder ("B" mix) and wearing course ("C" mix), to the bituminous mixture laboratory. For the different experimental pavements the Maine Department of Transportation pavement technicians designed and recommended the binder content by the Hveem procedure.[4] Marshall test results were completed for additional design data. While the pavement designs were being completed, the bituminous concrete batch plant was inspected and approved by a Department inspector. Personnel had been assigned to inspect the mix at the plant and on the street while others were assigned to document placement and compaction of the pavement.

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Samples of the aggregate stockpiles were obtained from the Benton plant site and delivered to the Bituminous Concrete Laboratory in Bangor. AC-10 asphalt cement was obtained from the Koch Asphalt plant in South Portland. The powdered sulfur, which originated from Irving Oil and obtained from the Delta Chemical plant in Searsport, Maine, was brought from storage.

The "B" mix binder course aggregates, which 3/4 inch, 1/2 inch, crusher reject sand and blend sand stockpile samples, were combined at the contractors recommended blend of 46, 9, 41, and 4 percent, respectively into 20,000 grams total sample. The gradation curve is shown in Figure 5. The blend was then submitted to the course and fine sieve laboratories where the total sample was broken down into the various fractions retained on specific sieves to the pan. The material was then returned to the Bituminous Laboratory so that the fractions could be recombined at the contractor's submission into 1,200 gram units meeting the job mix formula which is required to be within MeDOT specifications as noted in Table V. The sulfur aggregates and asphalt cement were then placed in ovens and brought to a mixing temperature of approximately 285°F.

All bituminous concrete mixes, within the State, have been designed by the Hveem test procedure[5] except for airport overlays which have required Marshall test results as part of the project specification. The control mix and the 30/70, 20/80, and 10/90 SEA mixes were therefore designed by the Hveem concept. The Marshall data were developed to produce additional information. SEA mix design experience obtained during the preparation for the 1979 - First Field Trial with Sulfur Extended Asphalt (SEA) binders[1] plus the information submitted by the 1979 Special Report put out by the National Asphalt Pavement Association (NAPA) facilitated the SEA mix designs required for the interstate project. The binder course gradation curve is denoted in Figure 5 and the corresponding mix

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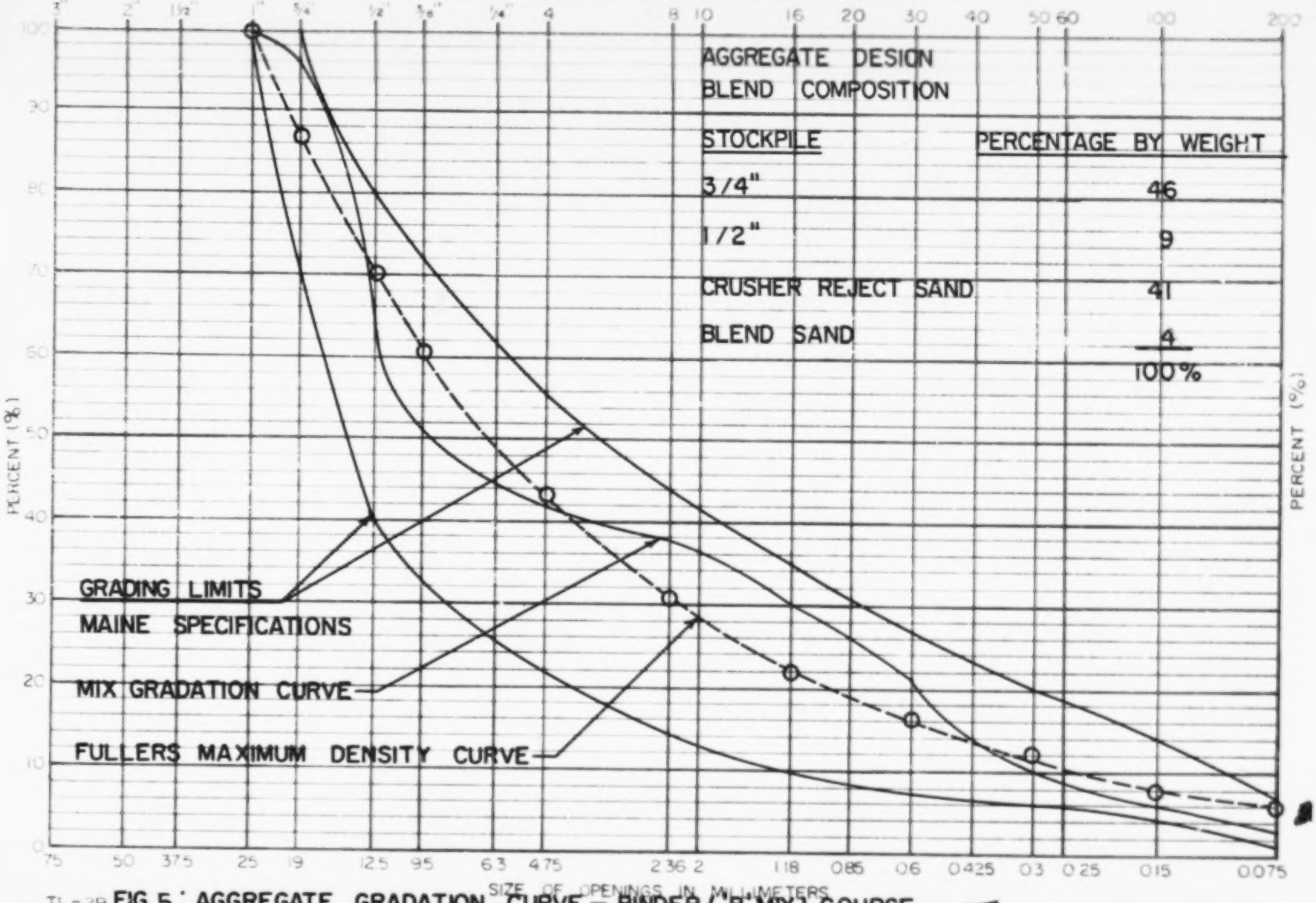
TESTING SECTION

AGGREGATE GRADATION CURVES

U.S. STANDARD SIEVE NUMBERS


3" 2" 1½" 1" ¾" ½" ⅜" ¼" 4 8 10 16 20 30 40 50 60 100 200
AGGREGATE DESIGN
BLEND COMPOSITION
STOCKPILE
PERCENTAGE BY WEIGHT
3/4" 46
1/2" 9
CRUSHER REJECT SAND 41
BLEND SAND 4
100%
GRADING LIMITS
MAINE SPECIFICATIONS
MIX GRADATION CURVE
FULLERS MAXIMUM DENSITY CURVE
PERCENT (%)
PERCENT (%)
100 90 80 70 60 50 40 30 20 10 0
75 50 37.5 25 19 12.5 9.5 6.3 4.75 2.36 2 1.18 .085 .06 .0425 .03 .025 .015 .0075
SIZE OF OPENINGS IN MILLIMETERS

TL-29 FIG. 5 : AGGREGATE GRADATION CURVE – BINDER ("B" MIX) COURSE

design data is listed in Table VI.

The same laboratory procedure was exercised for the design of the wearing course. The wearing course gradation curve is shown in Figure 6 and the mix design data is listed in Table VII.

TABLE V AGGREGATE SPECIFICATIONS - BITUMINOUS CONCRETE

Sieve	PERCENT PASSING					
	"B" Mix		"C" Mix		"D" Mix	
	From	To	From	To	From	To
1"		100				
5/4	70	100		100		
1/2	40	80	90	100		100
3/8			65	100	95	100
#4	22	55	40	70	60	80
#8	14	44	26	52	46	65
#16	10	35	17	40	25	55
#30			10	30	16	40
#50	6	20	7	22	10	30
#100	4	14	4	14	6	22
#200	1	7	2	7	3	8

Construction

Hot Mix Plant

The sulfur extended asphalt mix was produced with the same 8,000 pound portable batch plant (built by Warren Bros., Inc.) that was used on the 1979 SEA project. The installation is shown by Photo 4.

The plant was equipped with four cold feed bins, an oil fired drum aggregate dryer (which was modified to an experimental wood pellet heating system midway through the project), and a bag house collector which returned the fines to the mix. The single asphalt storage tank was connected to the plant with a recirculating asphalt line. An insulated sulfur ferry trailer (5,000 gallon capacity) owned by Irving Oil was used as the plant sulfur storage tank. A second

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TABLE VI MIX DESIGN RESULTS, BINDER ("B" MIX) COURSE

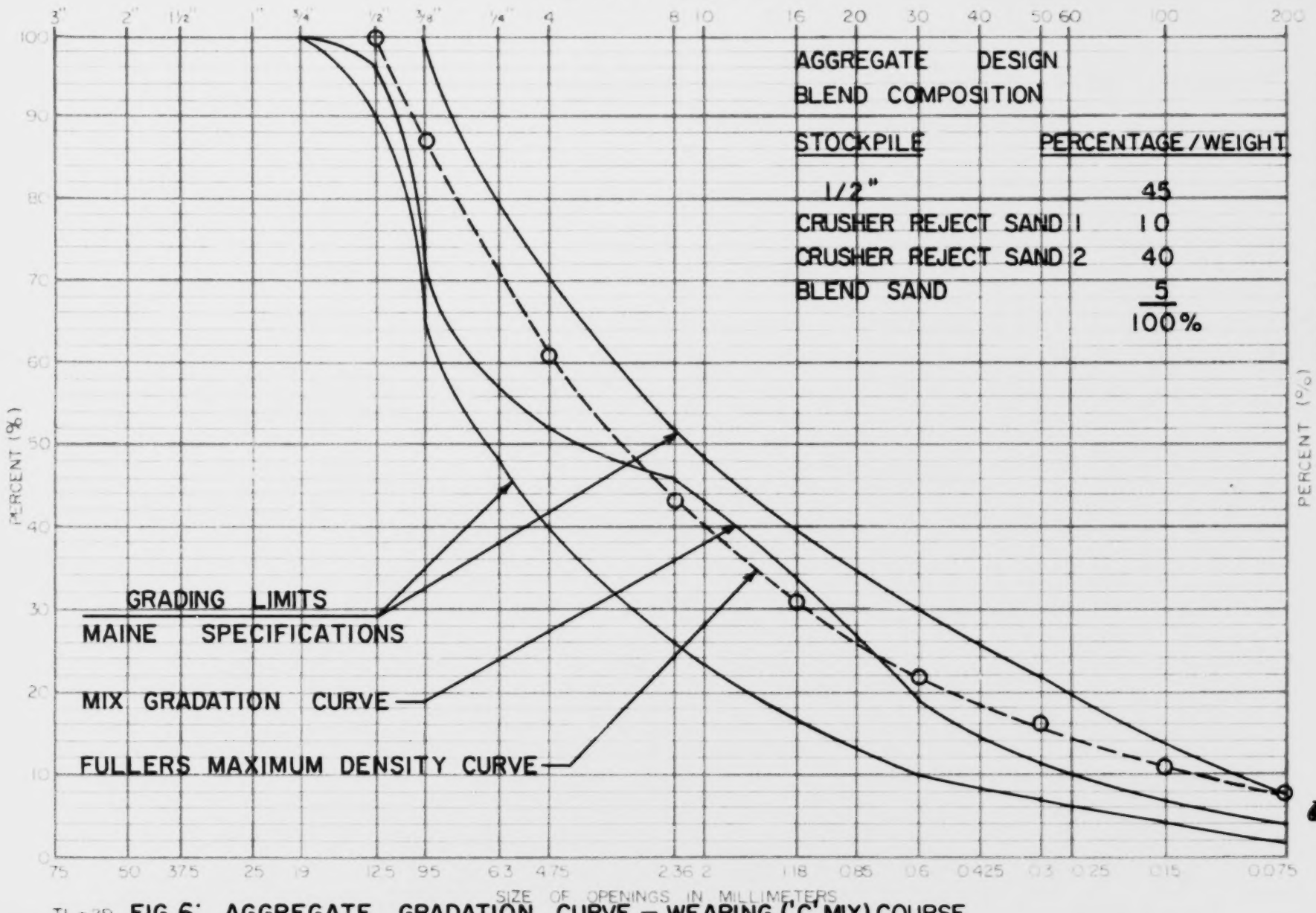
BLEND	% BINDER	HVEEM			MARSHALL		
		DENSITY	STABILITY	COHESION	FLOW	STABILITY	VMA
Control (AC-10)	4.0	98.4	48	218.4	----	----	----
	4.5	97.1	42	334.2	10	2163	15.7
	5.0	97.7	33	229.8	10	1930	15.0
	5.5	99.9	25	238.1	12	1997	15.0
	6.0	99.3	0	163.5	----	----	----
SEA 30/70	5.0	96.2	54	217.4	----	----	----
	5.5	96.7	53	201.1	10	2045	17.2
	6.0	98.4	40	235.9	11	2655	16.5
	6.5	98.6	28	197.5	15	1901	17.6
	7.0	99.4	0	173.8	----	----	----
SEA 20/80	4.7	95.8	46	171.2	----	----	----
	5.2	98.1	45	219.2	10	1730	16.0
	5.7	99.0	29	171.5	9	1436	16.3
	6.2	99.5	0	198.1	13	1426	16.1
	6.7	99.7	0	133.5	----	----	----
SEA 10/90	4.4	95.8	45	163.5	----	----	----
	4.9	97.1	42	236.5	10	1405	16.0
	5.4	98.3	40	138.9	10	1395	15.2
	5.9	98.8	23	215.1	14	1360	15.4
	6.4	99.1	26	228.7	----	----	----

MAINE DEPARTMENT OF TRANSPORTATION

TESTING SECTION

AGGREGATE GRADATION CURVES

U.S. STANDARD SIEVE NUMBERS


3" 2" 1½" 1" ¾" ½" ⅜" ¼" 4 8 10 16 20 30 40 50 60 100 200
100 90 80 70 60 50 40 30 20 10 0
PERCENT (%)
AGGREGATE DESIGN
BLEND COMPOSITION
STOCKPILE PERCENTAGE/WEIGHT
1/2" 45
CRUSHER REJECT SAND 1 10
CRUSHER REJECT SAND 2 40
BLEND SAND 5
100%
GRADING LIMITS
MAINE SPECIFICATIONS
MIX GRADATION CURVE
FULLERS MAXIMUM DENSITY CURVE
75 50 37.5 25 19 12.5 9.5 6.3 4.75 2.36 2 1.18 0.85 0.6 0.425 0.3 0.25 0.15 0.075
SIZE OF OPENINGS IN MILLIMETERS

TL-29 FIG. 6: AGGREGATE GRADATION CURVE – WEARING ('C' MIX) COURSE

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TABLE VII MIX DESIGN RESULTS, WEARING ("C" MIX) COURSE

BLEND	% BINDER	DENSITY	STABILITY	COHESION	FLOW	STABILITY	VMA
Control (AC-10)	5.0	95.9	44	192.5	----	----	----
	5.5	98.0	39	86.8	9	1700	17.5
	6.0	99.1	34	159.3	10	1840	17.0
	6.5	99.9	0	174.5	13	1742	17.1
	7.0	99.9	0	174.1	----	----	----
SEA 30/70	5.5	95.7	47	216.2	----	----	----
	6.0	97.0	44	242.9	----	----	----
	6.4	-----	----	-----	10	1618	19.3
	6.5	97.8	38	216.1	----	----	----
	7.0	98.9	17	274.7	----	----	----
	7.2	-----	----	-----	8	1489	18.7
	7.5	99.8	0	138.7	----	----	----
SEA 20/80	5.5	96.8	35	156.5	----	----	----
	6.0	98.8	25	250.4	11	1763	17.6
	6.4	-----	----	-----	14	1758	17.8
	6.5	99.0	23	190.0	----	----	----
	6.8	-----	----	-----	14	2023	18.0
	7.0	100	0	197.3	----	----	----
	7.5	100	0	215.9	----	----	----
SEA 10/90	5.4	97.5	40	248.5	----	----	----
	5.8	98.7	38	178.5	10	1914	17.2
	6.2	98.8	36	195.8	11	1800	16.9
	6.6	100	15	156.1	11	1592	17.0
	7.0	100	0	187.4	----	----	----

recirculating feeder line was installed to take care of the sulfur demand. Both the asphalt and the sulfur systems included insulated lines, gear pumps, and 3-way valves which controlled the flow into the plant's asphalt weigh bucket. (See Figure 7). The automatic plant control system was used during the production of the regular mix. However, during the production of the SEA mix, the automatic system was by-passed and the SEA mix was produced manually because of the inclusion of the binder additive (sulfur).

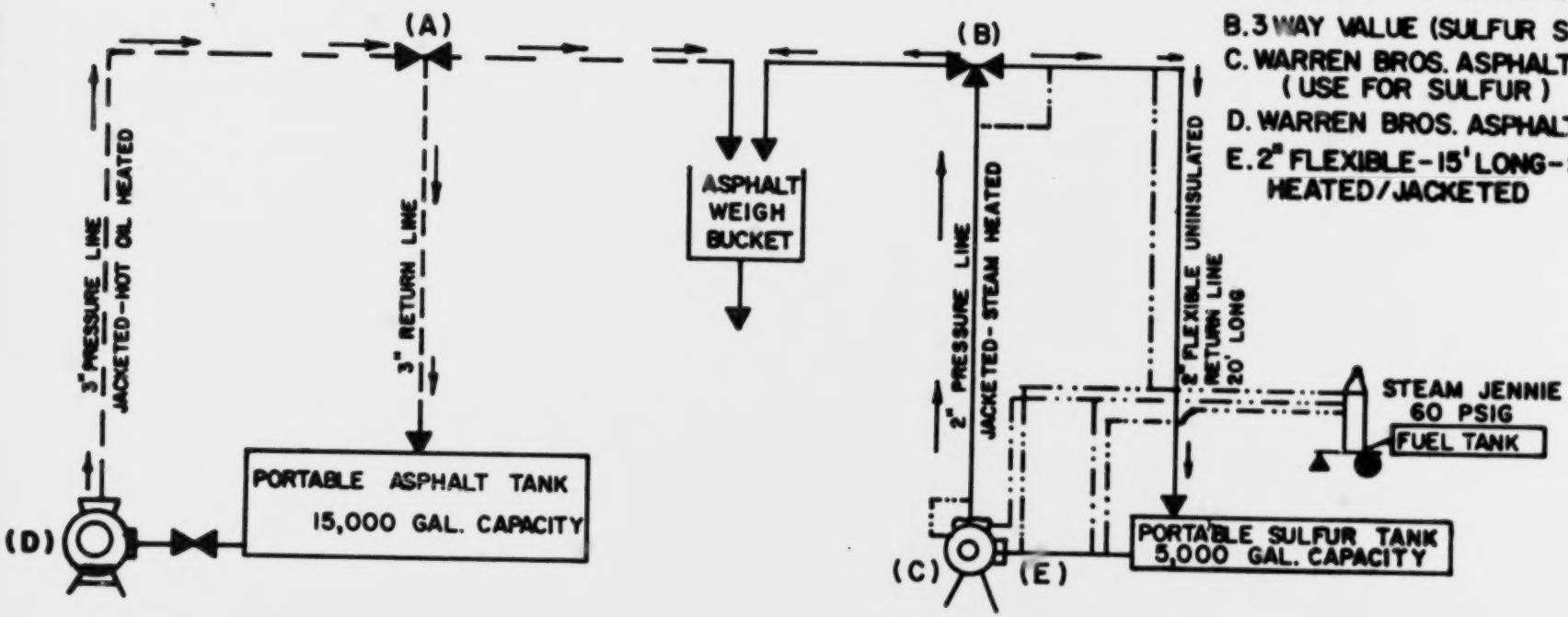
The addition of the portable sulfur storage facility enabled Irving Oil to supply sulfur via ferry trucks to the plant as required. Sulfur was pumped with a steam jacketed pump, fabricated by Warren Bros., Inc., through a steam jacketed 2-inch pipe line from the tank to the 3-way demand valve. The majority of the return line from the 3-way valve to the tank was also steam jacketed except for a short vertical flexible pipe which returned the sulfur flow into the tank during intervals of zero demand. It was necessary to maintain the sulfur flow to prevent it from solidifying in the lines.

An oil fire steam jennie, capable of producing steam at 60 psi (2.2 2Kg/sq CM) was used to maintain the temperature of the sulfur in the portable sulfur tank and the recirculating system.

Hauling Equipment

The mix was transported from the plant to the street in non-modified, uninsulated dump trucks. The equipment did have, as specified, canvas covers to retard the dissipation of residual heat and to protect the mix from inclement weather. The truck body release agent, applied with a straight nozzle, was used as required to prevent the mix from adhering to the truck bodies. The number of trucks required to transport the mix to the job site varied from eight to eleven or increased in proportion to the haul distance.

ASPHALT HOT MIX PLANT



NOTES

A. 3 WAY VALUE (ASPHALT SYSTEM)
B. 3 WAY VALUE (SULFUR SYSTEM)
C. WARREN BROS. ASPHALT PUMP (USE FOR SULFUR)
D. WARREN BROS. ASPHALT PUMP
E. 2" FLEXIBLE - 15' LONG - STEAM HEATED/JACKETED

SCHEMATIC: ASPHALT & SULFUR FLOW

LEGEND

- ASPHALT LINES
- SULFUR LINES
- STEAM LINES

FIG. 7: SCHEMATIC FLOW FOR THE ASPHALT AND SULFUR INSTALLATION

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Paver Train

The mix, both the binder and wearing course, was placed with a rubber tired Blaw Knox, PF 180 H paver. The paving widths varied from ten feet for the breakdown shoulder, twelve feet for the travel lane, and sixteen feet for the combined passing lane and the passing lane shoulder. A steel wheel 10-ton Galion roller immediately behind the paver was used as a breakdown roller, intermediate rolling was accomplished with a 7 wheel, 5 to 10-ton Brothers rubber tired roller, and final rolling was completed with a 3 wheel, 20-ton Buffalo Springfield roller.

Construction Procedures

Sulfur

The sulfur was obtained from the Irving Oil Refinery in St. John, Province of New Brunswick, and delivered to the project in insulated ferry trucks owned by a subsidiary of Irving Oil. The first shipment of liquid sulfur (300°F) was transported to the job site on Tuesday, May 19, 1981. The sulfur temperature was found to be 255°F at 9:00 a.m. at which time steam heat was utilized to increase the temperature to 270°F. This was accomplished with a steam jennie operated at 60 psi.

The sulfur delivery dates and tonnage from St. John are noted in Table VIII.

TABLE VIII SULFUR SHIPMENTS

Delivery Date	Delivered Tons	Accum. Tons
May 19, 1981	22.09	22.09
June 4, 1981	25.45	47.54
June 11, 1981	25.05	72.59
June 24, 1981	22.56	95.15
June 26, 1981	25.32	120.47
July 8, 1981	25.46	145.93
July 14, 1981	22.62	168.55
July 20, 1981	25.26	193.81
July 28, 1981	22.58	216.39

SEA Mix Preparation

Because the binder extender (sulfur) was injected into the asphalt weigh bucket immediately after the required asphalt was placed in the weigh bucket, the 8,000 pound plant's automatic control system had to be by-passed. The entire SEA placement or about 6,500 4-ton batches was produced manually by the batch plant operator. Three different SEA blends were specified on the project; therefore, a state inspector was made available to document the batch weights at random intervals.

The batch weight documentation included the asphalt weight, the combined weight of asphalt plus sulfur, and the aggregate weight for each batch produced.

The plants total mixing time, for the dry mix and the wet mix cycle, was increased from about 40 to 55 seconds per batch because of the manual operation. The 8,000 pound batch was dumped into a waiting truck and the batching sequence was continued. The plant inspector obtained mix samples at random intervals from the trucks to verify specification compliance.

Typical batch weights and plant reports are shown in Appendix D.

Laydown

The most difficult scheduling for the project was that of the pavement placement on the southbound lane for the southerly one-third of the project as it was specified to be completed before any work commenced on the other sections. The 30/70 SEA pavement was first placed south of the Hinkley Road Interchange on the southbound lane. Both the 20/80 and the 10/90 SEA blends were placed north of the Hinkley Road Intersection. Even though the project scheduling was quite difficult, the entire placement proceeded very smoothly.

The 30/70 SEA pavement laydown commenced on Wednesday, May 20, 1981. At 6:05 p.m. the first load of binder was placed on the southbound passing lane at Station 1381+75 and continued southerly to Station 1372+50 ending at 7:30 p.m. The day was clear with a temperature range from 40°F in the a.m. to the low 70's at noon and remained constant for the remainder of the day.

It was noted on the daily paving report (located in Appendix E) that the flushing problem on the adjacent pavement was corrected when the operation changed to the SEA pavement. The passing lane of the 30/70 SEA section was completed on Thursday, May 21, 1981. The travel lane commenced on May 29, 1981 and was completed on June 4, 1981. The travel lane shoulder placement commenced on June 3, 1981 and was completed on June 4, 1981. The placement of the 30/70 SEA wearing course commenced on June 10, 1981 and was completed June 3, 1981.

Upon completion of the southern portion, the paving operation was moved to the northern one third of the project. The paving commenced north of Mutton Lane overpass (Station 1605±) and continued to the Johnson Flat Road overpass (Station 1789±) in the Town of Pittsfield. The same placement procedure was used, that is, three passes per layer for both the northbound and southbound lanes. The placement of the 20/80 and the 10/90 SEA sections was accomplished with the same ease as regular asphalt bound pavements.

The SEA placements were completed on Monday, August, 4, 1981. The SEA pavements included 2,726.96 tons of 30/70 blend, 5,897.45 tons of 20/80 blend, and 17,541.88 tons of 10/90 blend of sulfur and asphalt for a total SEA placement of 26,166.29 tons. The project was completed Friday, October 16, 1981.

The weather and placement data is shown in Table IX.

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TABLE IX SEA PLACEMENT - WEATHER

DATE	TEMPERATURE A.M.	NOON	P.M.	REMARKS
5/20	40	74	68	clear and warm
5/21	44	76	64	clear and warm
5/29	50	66	60	partly cloudy a.m./rain p.m.
6/03	66	78	78	clear and warm
6/04	66	78	78	clear and warm
6/10	60	80	78	clear and hot
6/12	52	80	72	clear & cool a.m./partly cloudy & hot p.m.
6/18	68	80	78	clear and hot
6/24	68	82	78	clear
6/25	60	69	68	cloudy & showers a.m./clearing p.m.
6/26	64	82	82	clear and hot
7/07	72	88	88	clear and hot
7/08	66	88	88	clear and hot
7/09	66	80	80	cloudy a.m./clearing p.m.
7/10	68	82	82	sunny
7/15	56	72	72	cloudy
7/16	50	80	82	clear and warm
7/17	70	85	88	sunny, partly cloudy, and hot
7/20	64	66	66	cloudy a.m./light rain p.m.
7/22	68	90	80	clear and hot
7/23	46	86	82	clear and hot
7/24	60	88	88	hot
7/27	68	78	78	overcast a.m./clear and sunny p.m.
7/28	52	76	66	clear and hot
8/03	62	88	84	clear and warm
8/04	63	85	82	clear

Safety and Environmental Monitoring

Private industry considers sulfur a non-hazardous product even though the material is transported in a liquid state. Shipments of liquid sulfur (20 to 30 ton loads) are transported over the highways in specially insulated tractor trailers. Barges and railroad cars are utilized to haul larger qualities. Safety requirements for handling the product, which include hauling, heating, and storage procedures, have been established by the industry.

Safety

Elemental solid sulfur is transformed from a solid to a liquid state at 240°F. At temperatures above 320°F, sulfur changes from a liquid to a viscous, honey like substance as denoted in Figure 8. Small shipments of sulfur are normally loaded and transported at about 300°. Similar safety measurements have to be exercised when handling hot sulfur as are used with hot asphalt. Both materials are flammable at high temperatures and could be ignited with an open flame. Therefore, a smoking restriction is normally in effect in the presence of both materials. During the heating of sulfur, dust and fumes are liberated that could cause irritation to the membranes of the eyes, nose, and throat. Negligible amounts of Sulfur Dioxide (SO_2) and Hydrogen Sulfide (H_2S) gases were liberated in the temperature range of 240°F to 310°F but over 310°F the amount of toxic gases increases significantly.

Hydrogen sulfide (H_2S) is a very toxic gas, more deadly than cyanide. Fortunately, the H_2S gas concentrations were in the 0.02 ppm range which can be detected by its rotten egg odor. But if the gas concentration is much higher, a paralysis of the nasel membranes may occur which could negate the sulfur odor. A bituminous concrete plant is quite open to the air, thus any gases that may occur are rapidly dispersed.

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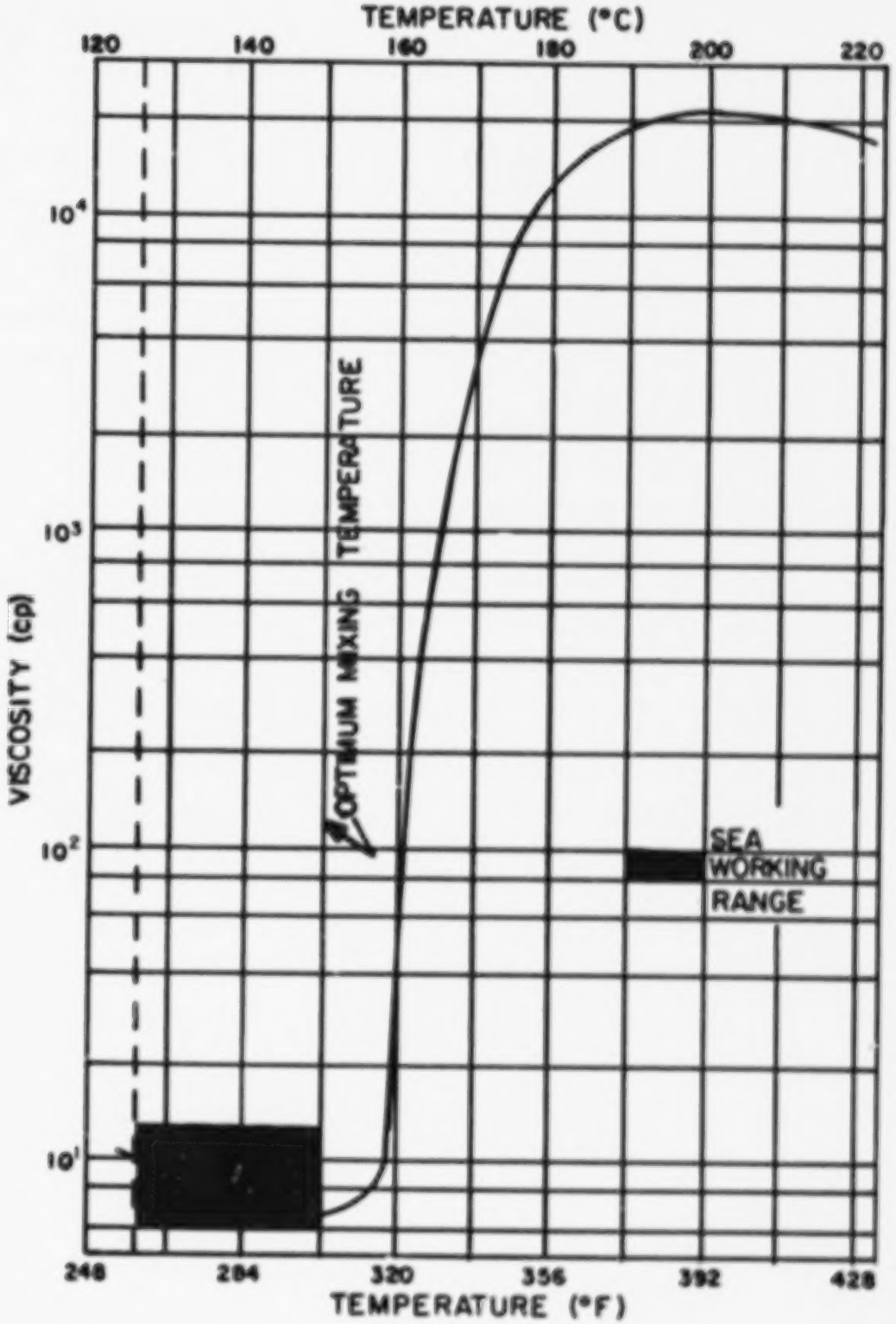

Figure 8 Temperature-Viscosity Chart for Liquid Sulfur

Environmental regulations have been established for the pollutants of the sulfur industry. OSHA has established that the allowable maximum concentrations for H_2S and SO_2 are 10 and 5 ppm, respectively. The American Conference of Governmental and Industrial Hygienists recommend a maximum allowable concentration for both of 10 ppm for an 8 hour exposure. OSHA also considers the total suspended particulates (TSP) and sulfates as a nuisance dust and has set the maximum allowable concentration at $15mg/m^3$.

Environmental Monitoring

Monitoring equipment was furnished by the Maine Air Quality and the actual monitoring of the sulfur emissions was accomplished by a Department Research technician. The pollutants of concern were H_2S, SO_2, and TSP.

The equipment used to monitor the H_2S was a "Matheson Toxic Gas Detector - Model 8014K with detector tubes" capable of measuring gas levels from 2 to 160 ppm. The samples were collected for a 12-minute sampling period Test equipment used to monitor the SO_2 levels was a portable "Interscan SO_2 Monitor - Model 1240 with a range from 0 to 5 ppm" Fifteen minute observations were obtained. The equipment used to monitor the TSP and sulfates was a General Metals High Volume Air Sampler which collects samples, under vacuum, upon a special filter 360 square centimeters in area. The filters were submitted to the Maine Air Quality Laboratory for analysis.

The tabulation of environmental data, indicates that both the H_2S and SO_2 reached a maximum of 2 ppm which is well within the allowable limit. (See Table X). The TSP measurements around the paver, ranged from 5.59 to 21.21 mg/m^3 which was above the OSHA recommended allowable concentration.

It was reported by Maine Air Quality that the TSP concentrations were quite high. They recommended that additional, more accurate monitoring should be made

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TABLE X ENVIRONMENTAL DATA DURING PLACEMENT

DATE	BLEND	WEATHER	H_2S	SO_2	TSP	SO_4	LOCATION
5/29	30/70	overcast, 60°F	2	0.50	-----	----	paver rear
5/29	30/70	rain	2	0.75	18.06	0.10	paver rear
6/03	30/70	7 mph, hazy	0	0.25	0.76	0.03	paver rear
6/03	30/70	7 mph, hazy	2	0.75-1.25	20.32	0.03	paver rear
6/10	30/70	8 mph, sunny	0	1.00-1.25	8.86	0.03	paver rear
6/17	30/70	4 mph, sunny	0	0.75-1.00	16.47	0.06	paver rear
6/18	30/70	7 mph, sunny	2	0.25-0.50	15.07	0.03	paver rear top
6/24	20/80	7 mph, sunny	2	0.25	18.38	0.02	paver rear
6/25	10/90	light rain	2	0.25	16.45	0.03	paver rear
6/26	10/90	7 mph, sunny	2	0.25-0.75	-----	----	paver rear
7/07	10/90	10 mph, sunny, 90°F	2	----	5.59	0.05	paver rear
7/08	20/80	5 mph, sunny, 90°F	2	----	21.21	0.04	paver behind hopper
7/08	20/80	7 mph, sunny 75°F	1	----	10.62	0.04	paver rear
7/10	20/80	15 mph, sunny, 90°F	--	----	19.30	0.05	paver rear on step

to establish operating guidelines to ensure the health and safety of the paver crew during the placement of SEA pavements.

The ceiling levels of toxic emissions established by OSHA may not necessarily be indicative to the degree of irritability the fumes cause to the crews. During hot, humid days with little or no wind, the emissions released by the SEA mix was extremely bothersome to the paving crew even though goggles and masks were made available. Perspiration build up under the protective devices caused nearly as many problems as the sulfur fumes.

Test Results

A number of different tests were completed for this period.

Plant Mix SEA Blend Comparison

Mix samples were randomly obtained, during production, from trucks en route to the placement. The samples include the control mix, 30/70 SEA blend, 20/80 SEA blend, and a 10/90 SEA blend. These samples were submitted to the Materials Laboratory where the Abson Method of the recovery of asphalt (AASHTO T 170-73, ASTM D 1856-69) was used to recover the regular and modified binding agents for laboratory analysis. The difference in binder qualities are shown in Table XI.

TABLE XI — BINDER SUMMARY

		SEA BLENDS					
	Control	10/90	% change	20/80	% change	30/70	% change
Pen.	80	125	+56	119	+49	103	+29
Vis. (Poises)	2930	613	(378)	880	(233)	1550	(89)

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As shown in Table XII, the pavement binder quality can be greatly enhanced with only 10 percent by weight or 5 percent by volume addition of sulfur to asphalt cement. The 20/80 and the 30/70 SEA blends show a substantial improvement over the control asphalt cement but the improvement was not as significant as the 10/90 blend.

Pavement Friction Resistance

Pavement frictional resistance (FN) of the new pavement was obtained to learn whether or not the new surface texture provided adequate drainage to insure vehicle maneuverability during wet pavement conditions. The measurements were obtained with a frictional resistance trailer fabricated by Maine Department of Transportation to ASTM E-274 specifications.

TABLE XII PAVEMENT FRICTIONAL RESISTANCE

Direction	Binder	Surface Frictional Resistance 6/23/80	7/02/81 Both Wheels	10/07/81 Right Wheel	10/13/81 Left Wheel	In
SB	SEA 10/90 F	48	Not completed	53.1	45.2	49.2
SB	AC-10	48	34	44.1	37.9	41.0
SB	SEA 30/70 F	48	41	50.8	42.3	46.6
SB	AC-10	48	42	47.1	41.6	44.4
NB	AC-10	45	Not completed	52.1	45.0	48.6
NB	SEA 20/80 F	45	Not completed	55.3	48.0	51.6

The above table results show that a SEA binder has the tendency to provide equal or better pavement friction characteristics than with a pavement bound with regular asphalt cement. Normally, the data submitted is the average obtained from both wheel paths. Therefore, the survey conducted on October 7 and October 13 were combined into a single FN. The SEA pavement yielded a FN of 2 to 8 points higher than the adjacent AC-10 pavement. The average of all three SEA sections was 49.1 and the average of the adjacent AC-10 control sections was 44.7.

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Approximately two weeks after the pavement was placed, FN values were obtained because of apparent wheelpath flushing. These tests indicated that the undesirable FN condition had substantially improved.

Pavement Rideability

A Mays Rideability survey has been conducted on the Interstate system each year for the last several years. The data have been used as one of the evaluating methods to determine the present serviceability index (PSI) of each constructed section to find out when a section should be scheduled for rehabilitation. The Mays results (inches per mile displacement of chart paper) was considered as an aid to determine the extent of repairs required to upgrade a section of road with the following ranges used for the preliminary recommendations:

Range	Rate	Treatment
Over 21	Poor	Overlay or reconstruct
17-21	Fair	Preventative maintenance required
7-21	Good	May need minor maintenance
0-7	Excellent	- - - - - - - - - - - -

Table XIII shows the relative comparison of the different experimental roadway sections.

TABLE XIII MAYS RIDEABILITY DATA

Direction	Section	Deflection - Inches Per Mile 6/12/80	3/3/81	10/8/81	PSI
SB	SEA 10/90	16.23	17.94	8.62	4-3
SB	AC-10 - control	12.73	10.16	10.52	4-3
SB	SEA 30/70	14.11	10.89	12.12	4-3
SB	AC-10 - control	13.80	13.72	7.98	4-3
NB	AC-10 - control	9.44	10.92	8.30	4-3
NB	SEA 20/80	5.99	7.46	9.74	4-3

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Pavement Deflections

Preliminary pavement deflection measurements were obtained on the Benton-Pittsfield experimental Interstate pavement overlay project on May 12, 1981. An 18 kip axle load was used to deflect the pavement. The deflections were measured with a Benkelman Beam at five locations for the six 500-foot test sites. The test sites were randomly selected for each change of experimental binder. The overlay, which included 1/2 inch of level course, 1/2 inch of a stone chip seal interlayer, 2 1/4 inches of binder course, and a 1 1/4 inch wearing course, was completed on August 26, 1981. Follow up Benkelman beam measurements were obtained on October 29, 1981. A comparison of the before and after deflections are noted in Table XIV.

TABLE XIV PAVEMENT DEFLECTIONS

#	Direction	Experimental Type	Station to Station		Averages Preliminary	Averages After Construction
1	SB	SEA 10/90 F	1780	1775	0.020	0.025
2	SB	SEA 10/90 F	1586	1581	0.022	0.026
3	SB	Control - AC-10	1457	1482	0.022	0.022
4	SB	SEA 30/70 F	1386	1381	0.026	0.022
5	NB	Control - AC-10	1650	1655	0.020	0.014
6	NB	SEA 20/80 F	1737	1742	0.020	0.010

A review of the before and after construction values obtained on the southbound lane of the interstate would make the reviewer somewhat skeptical of the Benkelman Beam results; the apparent strengthening of the northbound lane conforms to the expected results which could be anticipated with a four inch overlay.[6] Apparently, the reason that a deflection reduction in the southbound lane was not obtained was that the pavement deterioration was much greater in that lane which was verified by the crack survey results.

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DISCUSSION OF RESULTS

Laboratory evaluation of SEA with varying percentages of sulfur indicated that the modified binder qualities would be substantially improved when compared to the qualities of virgin asphalt. Three SEA weight blends were prepared (30/70, 20/80 and 10/90) and it was found that the 10/90 blend produced optimum improvement in recovered penetration values. Therefore, field sections were installed with all three SEA blends to determine whether or not the modified binders performed as well or better than regular AC binder. Also to make a relative comparison of the SEA binders in their ability to flex during movements of the underlying pavement and retard reflective pavement carcking. Pavement crack maps, each representing a five-hundred foot section of roadway, were obtained in the SEA experimental and control sections for comparison purposes. Past work by Phillips Petroleum indicated that small addition of sulfur (about 5 percent) would greatly enhance low temperature ductility characteristics of a sulfur modified asphalt cement. Therefore, it was believed that the 10/90 SEA section would perform better than the other SEA blends and the control sections. Field conditions with the severe Maine winters and heavy truck traffic should enable the evaluators to make a relative pavement performance comparison within two or three years.

Sulfur, as an extender of asphalt, would not be cost effective unless the sulfur price is less than half the asphalt price. The sulfur delivered price on this project was $120/ton and the asphalt delivered price was $193/ton; therefore, sulfur was substantially above the cost effective extender range. But if sulfur is considered an additive to enhance the qualities of asphalt cement through an increase in the performance/life ratio of pavement, then the cost of the additive would be insignificant.

Environmentally, elemental sulfur when used at a temperature range from 260° to 290°F can be considered a safe product with only negligible quantities of toxic gases [Hydrogen Sulfide (H_2S) and Sulfur Dioxide (SO_2)] liberated. Other SEA project monitorings have reported that low toxic gas emissions were in evidence but perhaps the effects of the sulfur fumes and particulates are more harmful to the paver work force than the minor toxic gas emissions. Headaches, irritated throat and nasal membranes were prevelant during the SEA laydown operation by members of the paving crew. One of the crew, responsible for guiding and dumping the trucks into the paver hopper, required medical attention to remove polyps from the throat upon completion of the work. This was the only job related case requiring treatment. The cause of the problem was not stated to be related to the irritating characteristics of the sulfur fumes that were released during the placement of 26,000 tons of SEA pavement. Nevertheless, the contractor paid the medical expenses for the treatment.

Evidently, similar findings have been made during SEA placements in Ontario because they recommended that restricted air vent goggles and dust masks should be used whenever necessary; however, other methods such as possitive ventilation with fresh air around the paver should be investigated.[7]

According to the roller operators, the SEA pavement was placed and densified with the same ease as a regular bituminous concrete pavement. The breakdown roller operator stated that the SEA pavement rolled easier than a conventional pavement. The intermediate and the final roller operators noticed no difference in the rolling required to densify the SEA pavement.

The highway system is one of the most important transportation networks in the nation and must be maintained. Nearly all the produce is transported into the Northeast over the roads. A break in the existing highway network, through lack of maintenance and repair, could cause undue hardship for the people at the end of the line. Therefore, it is necessary to investigate not only all available methods and procedures, but also new technology, to maintain the existing pavements.

CONCLUSIONS

Over 26,000 tons of SEA pavement were successfully used to overlay a portion of the experimental interstate project. The pertinent findings of the construction phase are as follows:

1. The "Direct Method" of mixing sulfur and asphalt was used satisfactorily for the entire SEA placement.

2. No problems were encountered during the design, fabrication, transportation, and placement of the SEA mix.

3. The SEA mix was placed and densified with the same effort as with other products having similar gradations.

4. Air Quality monitoring indicated that the sulfur gases (H_2S & SO_2) liberated were within the safe zone of the OSHA regulations.

5. Air Quality monitoring indicated that sulfur fumes and total suspended particulates (TSP) were generated at higher concentrations than the recommended maximum level of OSHA regulations.

6. Air Quality monitoring proved that similar concentrations of pollutants could be released regardless of the weight blend of sulfur used in a mix.

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7. The concentrations of sulfur fumes and particulates appeared to be directly proportional to the relative humidity during placement.

8. Laboratory results indicated that sulfur additions enhance the physical attributes of asphalt cement.

9. A positive ventilation system should be developed to protect the paver - laydown work force.

10. Pavements constructed with a SEA binding agent appear to have superior frictional characteristics.

REFERENCES

1. Gross, A.; "First Field Trials With Sulfur-Extended-Asphalt (SEA) Binders In Maine", FHWA-TS-80-240.

2. McBee, W. C. and Sullivan, R. A.; Bureau of Miners Report of Investigations, 1978, "Direct Substitution of Sulfur For Asphalt in Paving Materials", U. S. Department of Interior Library TN23.U7/No. 8303/622.06173.

3. Draper, H. L. and Gagle, D. W. and Holland, F. H. of Phillips Petroleum; "Modification of Asphalt Cement with Elemental Sulfur", paper presented at the Utah Bituminous Conference, March 1979.

4. Standard Specifications Highways and Bridges, Department of Transportation, Revisions of June, 1981, Section 702, p. 402.

5. Mix Design Methods for Asphaltic Concrete and Other Hot Mix Types, Asphalt Institute, Manual Series No. 2 (MS-2), Chapter 4, p. 33, March 1979 printing.

6. N. W. Lister; "Deflection Criteria for Flexible Pavements and the Design of Overlays", Civil Engineering Department, University of Michigan, January 1972.

7. Fromm, H. J. and Bean, D. C. and Miller, L.; "Sulphur-Asphalt Pavements Performance and Recycling", paper presented at the AAPT meeting held at San Diego, California, February 1981.

BEST DOCUMENT AVAILABLE

APPENDIX A

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CHANGE ORDER.	40
SPECIAL PROVISION, SECTION 403.	41
CONSTRUCTION REQUIREMENTS	42

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MAINE DEPARTMENT OF TRANSPORTATION

CHANGE OR EXTRA WORK ORDER

Change ORDER No. 4

PROJECT No. I-95-7(84)127 TOWN Benton Palmyra DATE April 22, 1981

To: (Contractor) Tilcon Warren You are hereby notified:

☒ The following change is authorized

☒ The following work is to be accomplished in accordance with the provisions of your Contract

PAYMENT WILL BE MADE: ☒ AT BID PRICES ☐ AT AGREED PRICES ☐ FORCE ACCOUNT

DESCRIPTION To establish the locations where the H.B.P./sulfur and the H.B.P./Chem-Crete shall be placed and to establish other blends, of sulfur extended asphalt in the H.B.P., than were called for in the contract.

This work ~~(was)~~ (has not) been accomplished.

REASON To investigate the feasibility of various blends of sulfur in the asphalt. This is Demonstration Project 54 - sulfur extended asphalt Work Order No. DTFH-71-80-50 Me-02.

To clarify the Special Provision Section 403 all experimental sections shall be pave full width main line and shoulders as indicated on the attached plan.

If the total tonnage of asphalt in the sulfur extended asphalt mix exceeds 1200 tons and/or if the total tonnage of sulfur exceeds 210 tons, reimbursement will be made to cover the additional material. With this assurance there will be no additional cost to the contract.

Resident (signed) Richard W. Amon (signed) Contractor (if required)

Do not write below this line — for office use only

Recommended:

Asst. Division or Project Engineer

☒ Participating ☐ Non-Participating

D.G.
(signed)

(Right of Way, if required)

(other, if required)

Dewey Gray
Construction Engineer

Approved:
DEPARTMENT OF TRANSPORTATION

By Ralph A. Stevens Date 5/7/81

Amt. available for Contingencies	0.00
Amt. Approved Orders to Date	605.00
Amt. of this Order	0.00
Total Amt. of all Orders	605.00
Balance of Contingent Fund	605.00

(This space for F.H.W.A. use)

APPROVED FOR FEDERAL PARTICIPATION

WALTER MITTON

JUNE 10, 1981

Benton to Palmyra
I-95-7(84)
August 5, 1980

SPECIAL PROVISION
SECTION 403
HOT BITUMINOUS PAVEMENT
(Treated Asphalt)

DESCRIPTION. This work shall consist of furnishing and placing hot bituminous pavement using asphalt cement which has been treated with Chem-Crete or Sulphur.

MATERIAL

GENERAL. Materials used in this work shall conform to the requirements of standard hot bituminous pavement with the exception that the paving asphalt shall be treated with an additional ingredient.

CHEM-CRETE. Chem-Crete shall be a proprietary item supplied by Chem-Crete Corporation, 2180 Sand Hill Road, Menlo Park, California 94025. Chem-Crete shall be added to the specified paving asphalt, with 1 part Chem-Crete to 9 parts paving asphalt, by weight, to obtain 10 parts of treated paving asphalt. The Chem-Crete treated paving asphalt shall be used in the standard hot bituminous pavement mix designs.

The Contractor shall notify the Engineer at least 30 days in advance of using the Chem-Crete to provide time to examine and test the source of asphalt to be mixed with the Chem-Crete.

SULPHUR. Sulphur shall be a commercial grade and shall conform to the following requirements:

Purity	95.5 percent, minimum
Ash Carbon	100 parts per million, maximum
Hydrocarbons	100 parts per million, maximum
Arsenic	0.25 parts per million, maximum
Selenium	2 parts per million, maximum
Color	Bright Yellow
Temperature -	
Liquid Phase 250°F, minimum; 300°F, maximum	

Sulphur shall be added to the specified paving asphalt by pumping into the asphalt weigh bucket in a 30 percent sulphur and 70 percent asphalt mixture ratio. Caution shall be exercised since sulphur releases toxic gases above 315°F. Below 240°F, sulphur may solidify. The sulphur treated paving asphalt shall be used in the standard hot bituminous pavement mix designs.

CONSTRUCTION REQUIREMENTS

GENERAL. Hot bituminous pavement using treated asphalt shall conform to all requirements of mixing and placing standard hot bituminous pavement.

Goggles and respirators shall be available for each worker, i.e., rakers, paver operators, roller operators and others, during the placement of hot bituminous pavement with sulphur.

METHOD OF MEASUREMENT AND BASIS OF PAYMENT. Hot bituminous pavement placed under these special provisions will be measured and paid for as provided for standard hot bituminous pavement. There will be no separate payment for furnishing and adding Chem-Crete or for furnishing and adding sulphur. All such costs shall be considered included in the contract unit price for the respective treated hot bituminous pavement pay item.

Payment will be made under:

Pay Item		Pay Unit
403.302	Hot Bituminous Pavement with Chem-Crete, Grading B	Ton
403.303	Hot Bituminous Pavement with Chem-Crete, Grading C	Ton
403.312	Hot Bituminous Pavement with Sulphur, Grading B	Ton
403.313	Hot Bituminous Pavement with Sulphur, Grading C	Ton

APPENDIX B

Photo No.	Description	Page
1.	Preliminary Crack Survey.	44
2.	Typical Stakeout - Test Section	44
3.	Existing Pavement Condition	45
4.	Tilcon Maine Plant.	45
5.	Tilcon Maine Plant - Upper Deck	46
6.	Tilcon Maine Plant - Sulfur Pump and Tank Connection.	46
7.	Paver - Blaw Knox PF180H.	47
8.	Roller Train.	47
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10.	Protective Equipment.	48
11.	Protective Equipment.	49
12.	Environmental Monitoring Equipment.	49
13.	Pavement Texture - Control Section.	50
14.	Pavement Texture - SEA Section.	50

BEST DOCUMENT AVAILABLE

Photo 1: Preliminary Crack Survey

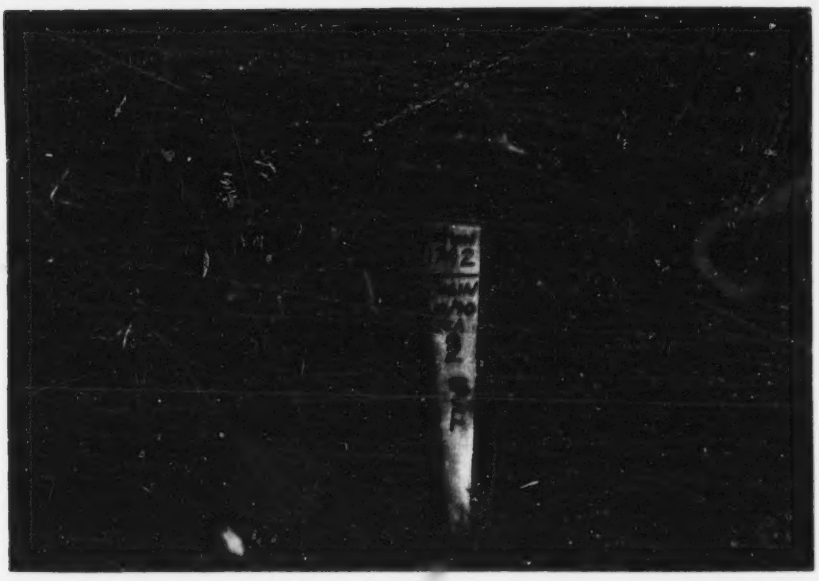

Photo 2: Typical Stakeout - Test Section

BEST DOCUMENT AVAILABLE

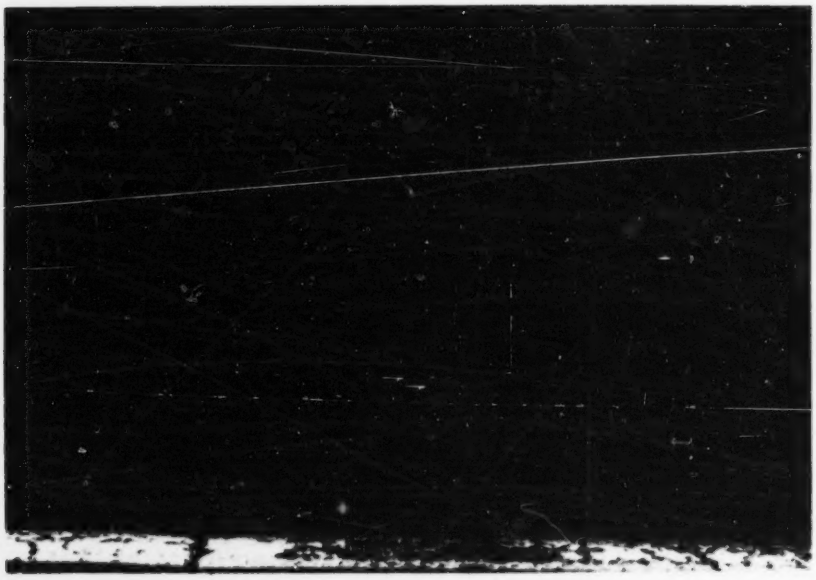

Photo 3: Existing Pavement Condition

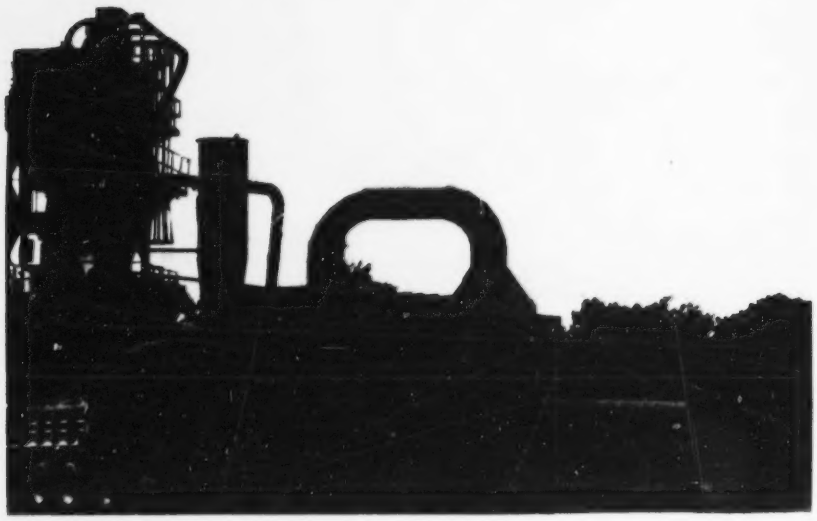

Photo 4: Tilcon Maine Plant

BEST DOCUMENT AVAILABLE

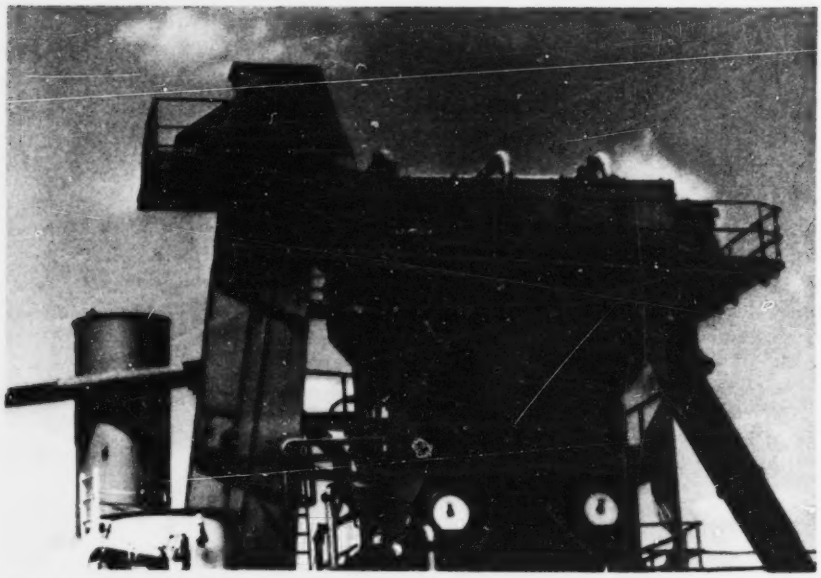

Photo 5: Tilcon Maine Plant - Upper Deck

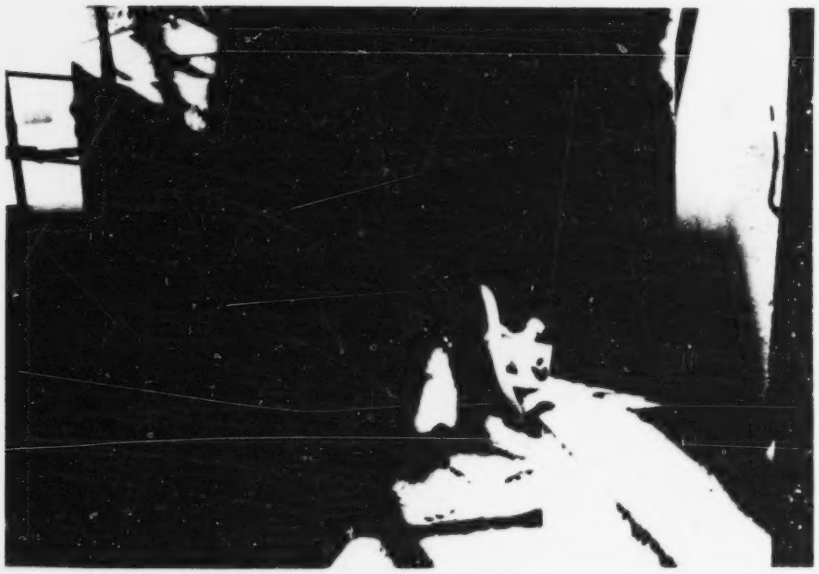

Photo 6: Tilcon Maine Plant - Sulfur Pump and Tank Connection

BEST DOCUMENT AVAILABLE

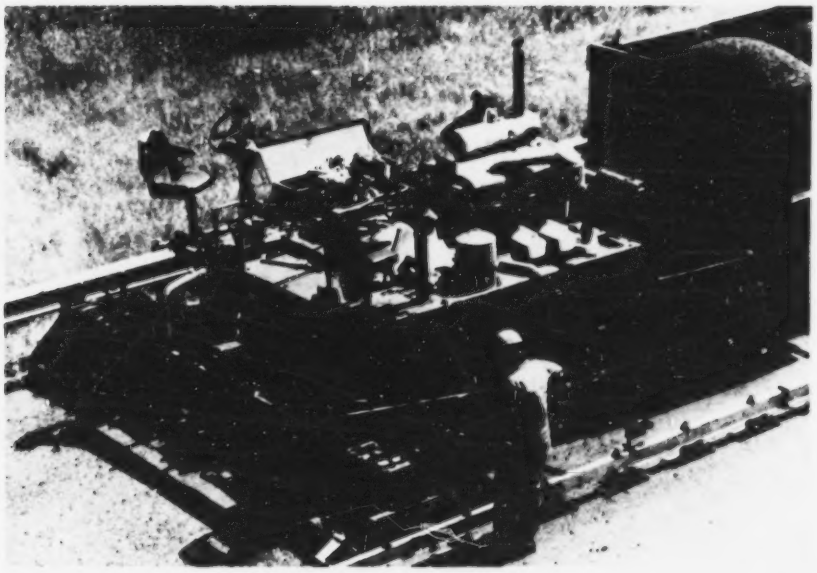

Photo 7: Paver - Blaw Knox PF180H

Photo 8: Roller Train

Photo 9: Sulfur Fumes

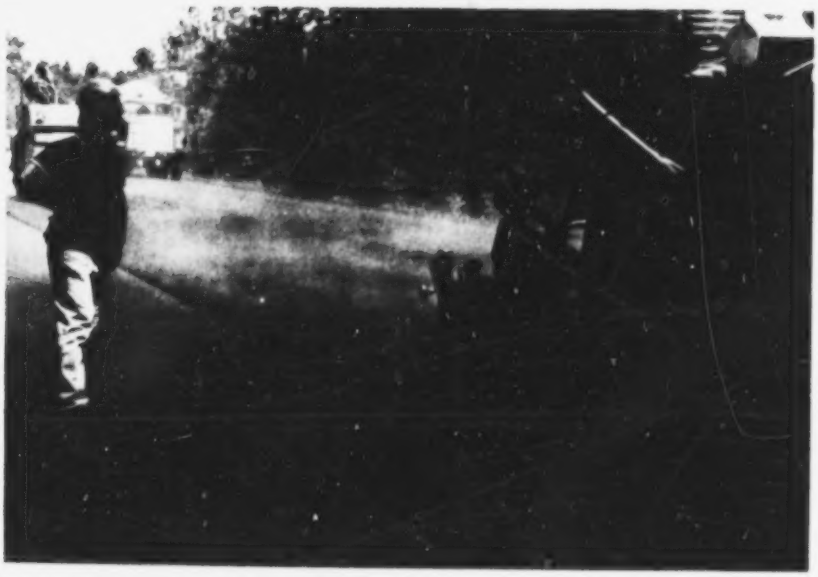

Photo 10: Proective Equipment

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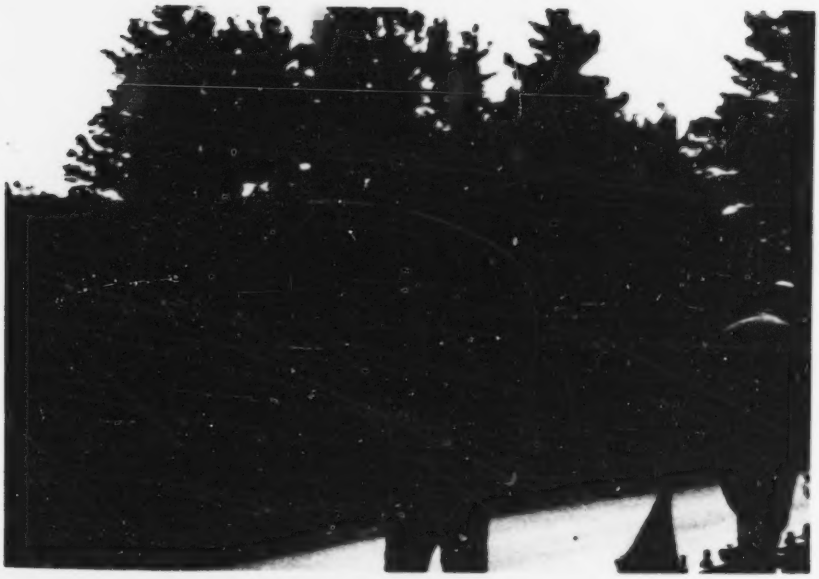

Photo 11: Protective Equipment

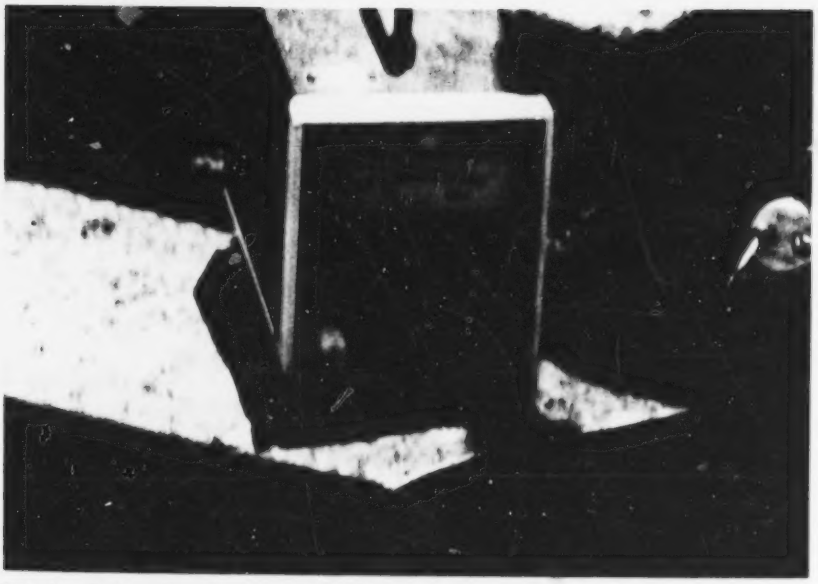

Photo 12: Environmental Monitoring Equipment

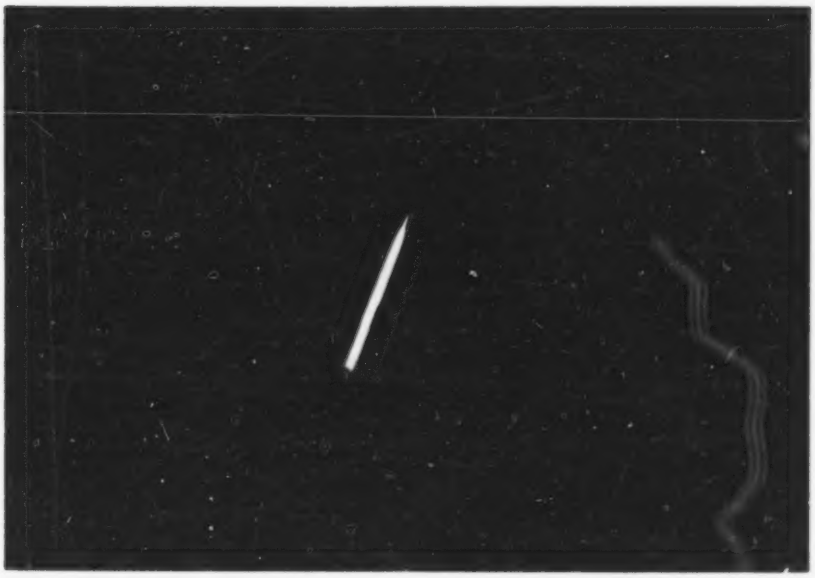

Photo 13: Pavement Texture - Control Section

Photo 14: Pavement Texture - SEA Section

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SULPHUR SOURCES FOR NORTHEASTERN UNITED STATES

Essex Chemical Company - 1401 Broad Street, Clifton, New Jersey 07015. Call Bill Van Treuren (201) 773-6300. Have own delivery trucks - resells from Exxon and others.

Texas Gul Company - Call Bill Mason or Bill Koppas in Houston (713) 658-9811, or Bo Gillette in Carteret, New Jersey (201) 842-6510. Basic producer (Texas), also handles material from local refineries. Will arrange for trucking.

The following produce sulphur from refinery operations in the area. Much of the production is either committed for customer or captive use, or is resold by distributors such as Essex and Texasgulf. We understand that Getty sells some directly to customers, however.

COMPANY	LOCATION	EST. PROD. 1,000 T/Y	CONTACT	TELEPHONE
Getty	Delaware City, DE	90	Harry Peters	(609) 662-6900
Exxon	Lindon, NJ	65	Don Schick	(713) 656-0209
Sohio	Marcus Hook, PA	36	Ivars Vecbastiks	(216) 575-5420
Mobil	Paulsboro, NJ	25	Gil Bradshaw	(604) 798-4291
ARCO	Philadelphia, PA	13	Bob Herman	(215) 557-2000
Texaco	Westville, NJ	5	Don Callaghan	(713) 666-8000
Sun	Claymont, DE	3	Jim Simmons	(800) 523-5540
Sun	Marcus Hook, PA	1	Jim Simmons	(800) 523-5540
Gulf	Philadelphia, PA	3	Jim Connor	(212) 397-1300
Bethlehem	Bethlehem, PA	5	John Reynolds	(215) 694-5391
Ashland Oil	Buffalo, NY	2	Brent Baker	(614) 889-4526
	CANADIAN FIRMS SERVING NEW ENGLAND AREA			
Laurentide Chemicals Ltd.	Montreal, Que.	84	Mr. Karras	(514) 645-1636
Irving Oil Ltd.	St. John, N.B.	70+	T. J. Cleary	(506) 657-7722
	SULFUR BROKER (SMALL SHIPMENTS)			
Chemical Enterprises, Inc.	Houston, Texas		James Hight	(713) 461-0606

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APPENDIX D

Page

BATCH WEIGHT LOG - 30/70 BLEND. 53

BATCH WEIGHT LOG - 20/80 BLEND. 54

BATCH WEIGHT LOG - 10/90 BLEND. 55

INSPECTOR'S DAILY PLANT REPORT. 56

PLANT DATA. 57

BEST DOCUMENT AVAILABLE

Mix Type: C

Blend: 30/70

INTERSTATE PROJECT

BATCH WEIGHT LOG

EXPERIMENTAL SEA PAVEMENT

DATE: 6/12/81

RECORDER: J. Osgood

Truck	Time	AC	AC+S	Agg.	Total
R-9	12:28	382	546	7440	7822
		381	546	7460	8006
		383	544	7440	7984
		378	547	7460	8007
G-1	12:34	380	548	7540	8088
		384	550	7450	8000
		384	547	7430	7977
		385	548	7455	8003
R-1	12:39	379	545	7450	7995
		382	547	7440	7987
		380	551	7450	8001
		381	544	7520	8064
R-2	12:45	382	547	7430	7977
		381	549	7430	7979
		385	547	7470	8017
		377	548	7440	7988
H-3	12:49	381	547	7470	8017
		380	543	7440	7987
		379	550	7450	8000
		378	543	7440	7983
C-1	12:54	381	546	7440	7986
		385	545	7440	7985
		381	548	7440	7988
		381	546	7450	7996
41	12:58	380	541	7520	8061
		381	551	7460	8011
		380	547	7450	7997
		382	544	7430	7974
111	1:04	381	548	7460	8008
		382	543	7450	7993
		379	544	7450	7994
		383	542	7470	8012

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INTERSTATE PROJECT

Mix Type: C

Blend: 20/80

BATCH WEIGHT LOG

EXPERIMENTAL SEA PAVEMENT

DATE: 7/17/81

RECORDER: J. Osgood

Truck	Time	AC	AC+S	Agg.	Total
C-1	6:23	410	514	7490	8004
		410	517	7510	8027
		413	515	7620	8135
		407	513	7740	8253
H-4	6:27	410	513	7700	8213
		415	512	7510	8022
		412	512	7580	8092
		413	513	6490	8003
R-9	6:31	417	512	7500	8012
		414	514	7660	8174
		412	512	7520	8032
		416	514	7510	8024
G-1	6:36	417	510	7520	8030
		410	510	7550	8060
		411	514	7510	8024
		416	514	7470	7994
R-1	6:40	414	513	7480	8003
		414	512	7500	8012
		407	512	7440	7952
		414	514	7510	8024
41	6:45	416	511	7600	8111
		417	512	7500	8012
		419	514	7470	7984
		414	509	7500	8009
R-2	6:49	414	513	7490	8003
		413	514	7470	7984
		---	512	7500	8012
		416	512	7480	7992

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Mix Type: C

INTERSTATE PROJECT

Blend: 10/90

BATCH WEIGHT LOG

EXPERIMENTAL SEA PAVEMENT

DATE: 7/20/81

RECORDER: J. Osgood

Truck	Time	AC	AC+S	Agg.	Total
C-1	1:09	447	496	7590	8086
		447	499	7540	8039
		448	500	7510	8010
		451	499	7520	8019
H-4	1:15	448	500	7520	8020
		451	499	7520	8019
		444	496	7530	8026
		446	498	7530	8028
H-3	1:19	445	498	7540	8038
		451	501	7550	8051
		447	497	7530	8027
		447	498	7520	8018
111	1:24	451	496	7520	8016
		447	499	7520	8019
		451	499	7540	8039
		451	500	7540	8040
199	1:28	446	498	7510	8008
		451	498	7560	8058
		452	497	7520	8017
		451	496	7520	8016
R-1	1:33	448	498	7530	8028
		447	498	7530	8028
		450	496	7620	8116
		448	498	7500	7998
R-9	1:37	446	499	7500	7999
		441	496	7530	8026
		451	497	7510	8007
		446	497	7510	8007

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

"B" Sulphur Mix

MIX INSPECTOR'S DAILY REPORT

(Bituminous Plant Mix Pavements)

Date May 21, 1981 Report No. 13

Project No. 95-7(84)

Town Benton-Palmyra

Weather Sunny Temp. 50° - 70°

Plant Tilcon Location Clinton

Hrs. Plant Operated 9 hr. 25 min.

Signed R. P. Stedman
Plant Inspector

COLD FEED PROPORTIONS

Aggregate	%	Sands	Blend
3/4"	46		
1/2"	9		
	4-1	Cr. Reject	
	4		X

BATCH WEIGHTS OR GATE SETTINGS

	Item No.	403.312		403.07		405:07			
Time	From	6:20		8:45		11:15			
	To	8:20		9:55		5:35			
		% Mix	Weight Inches	% Mix	Weight Inches	% Mix	Weight Inches	% Mix	Weight Inches
Bin 1		40	3200	40.	3200	40.	3200		
Bin 2		7.3	585	8.5	680	8.5	680		
Bin 3		7.8	620	5.3	420	5.3	420		
Bin 4		38.7	3100	41.2	3300	41.2	3300		
Filler									
Total		93.8	7505	95	7600	95	7600		
Bitumen		6.2	495	5	400	5	400		
Total Batch		100	8000	100	8000	100	8000		

TRUCK #	TRUCK NO. H-3			TRUCK NO. R-2			TRUCK NO. 3			TRUCK NO. 1			TRUCK NO. H-3			JOB MIX FORMULA	
TEST NO.	No. MRX-32			No. MRX-33			No. MRX-34			No. MRX-35			No. MGX-1			NO. TMI C-3	NO. TMI 8-5
DESCRIPTION	Grad. "B"			Grad. "B"			Grad. "B"			Grad. "B"			Grad. "B"			Grading	Grading
TIME	7:30		NOTES	9:30			12:45			3:25			4:08			"B"	"B"
TEMP.	260°			280°			265°			295°			270°			Item No.	Item No.
WT. SAMPLE	2168.5			2117			1832			1842			2340			403.312	403.07
WT. AGG.	2047.0		SEE	2006			1744			1750			2230			%A/C	%A/C
A/C (DIFF.)	121.5			111			88			92			110			5.0	4.8
% MIX	5.60			5.24			4.80			4.99			4.70			5.6	5.4
SIEVE SIZE	WT. RET.	% RET.	CUM. % PASS	WT. RET.	% RET.	CUM. % PASS	WT. RET.	% RET.	CUM. % PASS	WT. RET.	% RET.	CUM. % PASS	WT. RET.	% RET.	CUM. % PASS	TEMP 280°	TEMP 280°
2"	(30-70 blend)																
1½"	Pass #3			Pass #4			Pass #5			Pass #6			Pass #7				
1¼"																	
1"			99.9	00		100	0	0	100			100.0	0	0	100	100	
¾"	113	5.6	94.3	72	3.6	96.4	63	3.6	96.4	41	2.4	97.6	48	2.2	97.8	86 100	
½"	667	33.2	61.1	680	34.0	62.4	668	38.5	57.9	552	31.7	65.9	828	37.1	60.7	56 70	
⅜"	178	8.9	52.2	163	8.1	54.3	180	10.4	47.5	218	12.5	53.4	293	13.1	47.6	------	
#4	145	7.2	45.0	122	6.1	48.2	101	6.0	41.5	118	6.8	46.6	155	6.9	40.6	35 49	
#8	101	5.0	40.0	97	4.8	43.3	74	4.3	37.3	83	4.8	41.8	111	5.0	35.6	32 44	
#16	166	8.3	31.7	163	8.1	35.2	114	6.6	30.7	135	7.8	34.0	156	7.0	28.6	25 35	
#30	244	12.1	19.6	250	12.5	22.7	176	10.1	20.6	223	12.8	21.2	224	10.0	18.6	------	
#50	195	9.7	9.9	214	10.7	12.0	162	9.3	11.2	192	11.0	10.2	179	8.0	10.6	6 14	
#100	93	4.6	5.3	112	5.6	6.4	79	4.6	6.7	82	4.7	5.5	84	3.8	6.9	4 10	
#200	49	2.4	2.9	57	2.85	3.5	60	3.5	3.2	38	2.2	3.3	73	3.3	3.6	2 6	
PAN	59	2.9		71	3.55		56	3.2		57	3.3		80	3.6			
TOTALS	2010			2001			1736			1739			2231				

FT-51

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PLANT DATA

DATE	WEATHER	TEMP. RANGE	PLANT RUN TIME	TYPE MIX	ADDITIVE	BLEND	TONNAGE SUB TOTALS	TONNAGE DAILY TOTAL
5/20/81	sunny	50-70	8:40	B	-----	-----		2022
5/20/81				B	-----	-----	899	
5/20/81				B	Chem-crete	10/90	947	
5/20/81				B	sulfur	30/70	176	
5/21/81	sunny	50-70	9:25	B	-----	-----		2036
5/21/81				B	sulfur	30/70	369	
5/21/81				B	-----	-----	1667	
5/22/81	overcast	50-70	8:45	B	-----	-----		1802
5/26/81	sunny	70-80	12:05	B	-----	-----		2437
5/29/81	overcast	60	8:10	B	-----	-----		1743.5
5/29/81				B	-----	-----	787.6	
5/29/81				B	Chem-crete	10/90	683.7	
5/29/81				B	sulfur	30/70	272.2	
6/01/81	sunny	50-70	11:30	B	-----	-----		2213
6/02/81	sunny	40-75+	11:15	B	-----	-----		2490
6/03/81	sunny	50-70	9:35	B	-----	-----		1921
6/03/81				B	-----	-----	857	
6/03/81				B	sulfur	30/70	405	
6/03/81				B	Chem-crete	10/90	657	
6/04/81	overcast	50-70	7:05	B	-----	-----		1473
6/04/81	Heavy Rain 1400-1500 hrs.			B	sulfur	30/70	511	
6/04/81				B	-----	-----	962	
6/05/81	sunny	65-80	10:45	B	-----	-----		2480.5
6/08/81	sunny	50-70	12:15	B	-----	-----		1815
6/10/81	sunny	50-70	10:07	C	-----	-----		1854
6/10/81				C	-----	-----	1044	
6/10/81				C	Chem-crete		490	
6/10/81				C	sulfur	30/70	320	
6/11/81	overcast	60	10:05	C	control	-----		1750
6/12/81	sunny	50-70	10:44	C	-----	-----		1893

DATE	WEATHER	TEMP. RANGE	PLANT RUN TIME	TYPE MIX	ADDITIVE	BLEND	TONNAGE SUB TOTALS	TONNAGE DAILY TOTAL
6/12/81				C	control	-----	1119	
6/12/81				C	Chem-crete	10/90	515	
6/12/81				C	sulfur	30/70	259	
6/15/81	cloudy	60	10:20	C	control	-----		1505
6/17/81	Humid overcast	70+	10:25	B	control	-----		2462
6/18/81	sunny		12:10	C	-----	-----		2452
6/18/81				C	control	-----	1410	
6/18/81		Section Completed		C	Chem-crete	10/90	626	
6/18/81		Section Completed		C	sulfur	30/70	416	
6/19/81	fair		8:50	C	control	-----		1704
6/22/81	rain	60	2:45	C	control	-----		384
6/23/81	fair	65-70	11:00	C	control	-----		658
6/24/81	sunny	50-70	10:20	B	-----	-----		1897
6/24/81				B	control	-----	223	
6/24/81				B	sulfur	20/80	1674	
6/25/81	overcast	60-70	11:05	B	sulfur	10/90		2389
6/26/81	overcast	60-70	7:45	B	sulfur	10/90		1730.3
6/29/81	sunny	50-75	6:15	B	control	-----		1465
7/01/81	fog to sunny	70-80	9:25	B	control	-----		505
7/02/81	cloudy	70	4:00	B	control	-----		130
	Clinton (New burner installed)-wood pellet							
7/06/81	overcast	60	0:55	B	control	-----		31.76
Fairfield 7/06/81	P. cloudy Humid	80	5:15	B	control	-----		896
7/07/81	sunny	70-90	7:40	B	-----	-----		1429
7/07/81				B	control	-----	646	
	(sulfur pump broke down at 1440 hrs.)			B	sulfur	20/80	783	
7/08/81	sunny	60-90	10:30	B	sulfur	10/90		1847.6
7/09/81	High Clouds Clear Below	70-90	9:55	B	-----	-----		1848
7/09/81				B	sulfur	10/90	1423	
7/09/81				B	sulfur	20/80	425	

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DATE	WEATHER	TEMP. RANGE	PLANT RUN TIME	TYPE MIX	ADDITIVE	BLEND	TONNAGE SUB TOTALS	TONNAGE DAILY TOTAL
7/10/81	sunny	70-90	8:55	B	-----	-----		1871.2
7/10/81				B	control	-----	855.2	
7/10/81				B	sulfur	20/80	1016	
	Bridge Approach wwk - 2 plants							
7/14/81	overcast	70	4:00	B	control	-----		373
	Five in wood pellet feeder/AC weigh bucket overflowed - stock sulfur valve							
7/15/81	cloudy	60-80	8:00	B	sulfur	10/90		1567
7/16/81	clear	60	10:45	B	sulfur	10/90		1159
7/16/81				C	control	-----		1050
7/17/81	cloudy	60-80	8:33	C	-----	-----		1520.5
7/17/81				C	control	-----	876.96	
7/17/81				C	sulfur	20/80	643.5	
7/20/81	overcast	70	7:45	C	-----	-----		1544
Plant Down - 9-11 a.m. - to move paver, 4 p.m. - due to rain				C	sulfur	20/80	585	
7/20/81				C	sulfur	10/90	629	
7/20/81				C	control	-----	330	
7/21/81	rain	70	0					
7/22/81	cloudy a.m. clearing p.m.	70	12:20	C	-----	-----		2180
	Wood Burner 85% of day			C	control	-----	1649	
7/22/81				C	sulfur	10/90	531	
7/23/81	Cleary, sunny	54-70	10:15	C	-----	-----		1644
	Plant down - 8:30 to 9:30 to repair cold feed belt			C	control	-----	1450	
7/23/81				C	sulfur	20/80	194	
7/24/81	clear, sunny	50-70	9:10	C	-----	-----		1312
	Plant down - 11:05 to 12:30, paver moved NB to SB			C	sulfur	20/80	680	
7/24/81				C	sulfur	10/90	632	
7/27/81	overcast a.m. clear-sunny p.m.	60-70	7:20	B	sulfur	10/90		1130.5
7/28/81	clear	60-70	11:00	C	-----	-----		1520
	Last of SEA wearing course			C	sulfur	10/90	130	

DATE	WEATHER	TEMP. RANGE	PLANT RUN TIME	TYPE MIX	ADDITIVE	BLEND	TONNAGE SUB TOTALS	TONNAGE DAILY TOTAL
7/28/81				C	control	-----	1390	
7/28/81				B	sulfur	10/90		664
7/30/81	overcast am sunny pm	55-75+	10:10	B	control	-----		1759
7/31/81	sunny	57-80+	9:40	B	control	-----		1557
8/03/81	sunny	61-80°	10:45	B	-----	-----		2200
8/03/81				B	sulfur	10/90	1973	
8/03/81				B	control	-----	226.5	
8/04/81	overcast am humid-sunny pm	2 pm 86° 65-80°	11:45	B	-----	-----		1885
8/04/81				B	sulfur	10/90	242	
8/04/81				B	sulfur	20/80	1420	
8/04/81				B	control	-----	223	
8/05/81	Humid, hazy am 2:30 pm-rain 66°	12:00 80° 60°-80°	7:45	B	control	-----		1945.8
	Plant down @2:30 because of rain, burner on wood 85% of day							
8/06/81	overcast	60°	9:20	B	control	-----		1879
8/07/81	cloudy	58-60°	9:45	B	control	-----		697
8/10/81	overcast	65-80 @1500 hrs.	11:10	B	control			262
8/10/81				C	control			1266
8/11/81	foggy 65° @6am	65-80°	2:15	C	control			356.2
	Plant doan @ 10:30 a.m. - lost leaf springs in plant screen deck							
8/12/81	sunny	60-80°	6:25	C	control			1194.3
	Plant down @ 12:40 p.m. - hole in burner wall							
Fairfield					Bridge Approach work			
8/13/81	cloudy	70°	7:30	B	control			310
8/14/81	sunny	50-70°	10:35	C	control			1658.3
8/15/81	overcast	50-62 @2 pm	8:30	C	control			1531
					Bridge Approach Work			
8/17/81	overcast am	60°	8:00	B	control			310
8/18/81	sunny, clear	50-70°	11:00	C	control			1490
	Plant down 2 to 2:30 p.m. - cold feed belt bound up							

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DATE	WEATHER	TEMP. RANGE	PLANT RUN TIME	TYPE MIX	ADDITIVE	BLEND	TONNAGE SUB TOTALS	TONNAGE DAILY TOTAL
8/19/81	sunny	50-70°	12:20	B	control			661
		Clinton (Hinkley) plants last day/Remainder of mix from Fairfield Plant 8,000#				7,000#		
8/20/81	sunny	60-80°	10:45	C	control			703.3
8/21/81	sunny	40-80°	10:10	C	control			801
8/24/81	clear	50-70°	7:40	C	control			368
8/25/81	sunny	50-70°	8:30	C	control			352
8/26/81	sunny	50-70°	10:55	C	control			378

APPENDIX E

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SEA PLACEMENT DATA. 68

PAVING REPORT

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

Report No. 12 63
Date: Wed., May 20, 1981
Project No. 95-7(84)
Town: Benton-Palmyra

GENERAL INFORMATION

Paving Contractor: _____ Plant Location: _____
Superintendent: _____ Street Foreman: _____
Paving Machines, Make & Model: _____
Rollers: Make, Model, Weight: Same + three axle

ITEM NO.	GRAD.	Sta. to Sta. or Location	Theoretical: Depth	Theoretical: Width	Actual Sq. Yds.	Actual Tons	Actual Yield lbs./Sq. Yd.
403.07	"B"	SB Sec. (A) Passing Lane					
		& 4' Shld 1481+25 - 1434+0	2¼	16'	8400	899.24	214
403.302	"B"	Chem-Crete S.B. (Cont.)					
		1434+0 - 1381+75	2¼	16'	9289	946.75	204
403.312	"B"	SEA S.B. (Cont) 1381+75					
		1372+50	2¼	16'	1644	175.70	214

COMMENTS: Typical start up problems in A.M. Had problems with Flushing on Chem-Crete. Removed rubber tired roller. Seems to correct problem.

Time:	7:00 A.M. (Starting)	Noon	7:30 P.M. (Finishing)
Air Temp:	40 F	74 F	68 F
Weather:	clear-cool	clear-hot	clear-warm

CORE INFORMATION

Mix Grading	Core No.	Station	L.	R.	Thickness

TEMPERATURE OF MIX

Time	F
7:47	300
12:50	270
2:22	260
3:10	275
4:08	280

TRAFFIC OFFICERS

NAME	HOURS
Malley Agency	
D. Billings	
M. Harvey	all day
	TOTAL

ITEM NO.	Grad	DESCRIPTION	PREVIOUS TOTAL	TODAY'S TOTAL	CUMULATIVE TOTAL	
403.302	"B"	~~Base Course~~ Chem-crete		946.75	946.75	Tons
						Tons
403.312	"B"	~~Stab. Base Course~~ SEA 30/70		175.70	175.70	
						Tons
403.07	"B"	Primary Course		899.24	899.24	Tons
						Tons
		Wearing Course				Tons
						Tons
		Hand Placed				Tons
						Tons
403.10	"B"	Leveling Course	11,410.31	---	11410.31	Tons
		Tack Coat				Gals.
		Traffic Officers				M.H.
		Bit. Conc. Curb				L.F.

P-40-74

Signed _____ Paving Inspector

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DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS
CONSTRUCTION DIVISION

Truck
Tally Sheet

Material: Bituminous Concrete

Project No. 95-7(84) City Town Benton-Palmyra Ticket Taker J. Wade Date 5/20/81

Station	Time	Slip No.	Truck No.	Net Wt.	Total Weight	Remarks
	BINDER "B" MIX 403107			Section A Passing Lane		
		S.B.				
1481+25	7:15	63719	H-3	32000	32000	
1480+0	7:35	720	R-2	32220	64220	
1479+0	7:40	721	41	31860	96080	
1478+0	7:45	722	1	32000	128080	
1477+0	7:47	723	111	31920	160000	Temp 300°
1476+50	7:49	724	4	32100	192100	
1475+75	7:54	726	C-1	31960	255980	
1474+0	8:00	727	H-3	32220	288200	
1473+75	8:03	728	R-2	31900	320100	
1473+25	8:06	729	41	31900	352000	
1472+50	8:10	730	1	32140	384140	
1470+75	8:14	731	111	32120	416260	
1469+75	8:19	732	4	32200	448460	
1469+0	8:24	733	3	31960	480420	
1468+50	8:27	734	C-1	32140	512560	
1467+75	8:33	735	H-3	32340	544900	
1467+0	8:36	736	R-2	32120	577020	
1466+25	8:45	737	41	32600	609620	
1465+50	8:50	738	1	32540	642160	
1464+75	9:00	739	111	32200	674360	
1464+0	9:10	740	4	31900	706260	
1463+0	9:15	741	3	32000	738260	
1462+0	9:20	742	C-1	32120	770380	
1461+0	9:25	743	H-3	32000	802380	
1460+0	9:30	744	R-2	32320	834700	
1459+0	9:35	745	41	32120	866820	
1458+0	9:38	746	1	32000	898820	
1457+0	9:42	747	111	31900	930720	
1456+0	9:45	748	199	32600	463320	
1454+75	9:49	749	4	31940	995260	
1453+75	9:52	750	3	31940	1027200	
1452+75	9:55	751	C-1	32000	1059200	
1451+50	10:00	752	H-3	31900	1091100	
1450+50	10:03	753	R-2	32300	1123400	5644 S.Y.
1449+50						199.5#/S.Y.
						561.72

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DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS
CONSTRUCTION DIVISION

Truck
Tally Sheet

Material: Bituminous Concrete

Project No. 95-7(84) City Town Benton-Palmyra Ticket Taker J. Wade Date 5/20/81

Station	Time	Slip No.	Truck No.	Net Wt.	Total Weight	Remarks
1449+50	10:07	754	41	31900	31900	
1449+0	10:10	755	1	31880	63780	
1448+25	10:15	756	111	31820	95600	
1447+50	10:20	757	199	32720	128320	
1446+50	10:25	758	4	32700	161020	
1446+0	10:28	759	3	32120	193140	
1445+25	10:31	760	C-1	32500	225640	
1444+50	10:35	761	H-3	31860	257500	
1444+0	10:38	762	R-2	32020	289520	
1443+0	10:42	763	41	32120	321640	
1442+50	10:45	764	1	32040	353680	
1441+50	10:49	765	111	31940	385620	
1440+75	10:54	766	199	32400	418020	
1440+0	11:00	767	4	32000	450020	
1440+25	11:03	768	3	32000	482020	
1438+75	11:06	769	C-1	32480	514500	
1437+75		770	H-3	32180	546680	
1436+75	11:15	771	R-2	31820	578500	
1436+50	11:18	772	41	31980	610480	
1435+75	11:22	773	1	32400	642880	327.44
1434+75	11:30	774	111	32000	674880	275654
1434+0	Last Load Reg. Binder					245#/S.Y.
						899.14 tons
	Starting "B" w/Chem-crete 403.302					
1434+0	12:37	775	4	32520	32520	
1433+25	12:50	776	3	32100	64620	Temp. 270
1432+50	12:54	777	C-1	31960	96580	
1431+50	12:57	778	H-3	31480	128060	
1430+75	1:00	779	R-2	31720	159780	
1429+75	1:03	780	41	31540	191320	
1429+0	1:06	781	1	31640	222960	
1428+0	1:10	782	149	32120	255080	
1426+75	1:13	783	111	31400	286480	
1426+0	2:22	784	3	32600	319080	Temp. 260
1425+0	2:28	785	4	32100	351180	
1424+0	2:31	786	C-1	31640	382820	
1422+75	2:34	782	H-3	31640	414460	
1421+50	2:39	788	R-2	31420	445880	182#/S.Y.
1420+25	2:43	789	41	31520	477400	

DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS
CONSTRUCTION DIVISION

Truck
Tally Sheet

Material: Bituminous Concrete

Project No. 95-7(84) City Town Benton-Palmyra Ticket Taker J. Wade Date 5/20/81

Station	Time	Slip No.	Truck No.	Net Wt.	Total Weight	Remarks
1419+0	2:46	790	1	31540	508940	
1418+25	2:49	791	199	31440	540380	
1417+50	2:52	792	111	31520	571900	
1416+75	2:55	793	3	31400	603300	
1415+75	2:58	794	4	32000	635300	
1415+0	3:02	795	C-1	32020	667320	
1414+0	3:06	796	H-3	31640	698960	
1413+50	3:10	797	R-2	31620	730580	Temp 275
1412+50	3:14	798	H-1	31420	762000	
1411+75	3:17	799	1	31540	793540	
1411+0	3:20	800	199	31520	825060	
1410+25	3:23	801	111	32020	857080	
1409+50	3:26	802	3	32040	889120	
1408+75	3:29	803	4	31920	921040	
1407+0	3:55	804	C-1	32120	953160	
1406+75	4:00	805	H-3	32300	985460	196#/S.Y.
1405+75	4:04	806	R-2	32440	1017900	5200 S.Y.
1404+75						
1404+75	4:08	807	41	32420	32420	Temp 280
1403+75	4:10	808	1	32140	64560	
1402+75	4:14	809	199	32000	96560	
1402+0	4:18	810	111	32020	128580	
1401+25	4:21	811	3	31800	160380	
1400+50	4:24	812	4	31640	197020	
1399+75	4:28	813	C-1	31600	228620	
1398+75	4:31	814	H-3	31740	260360	
1398+0	4:36	815	R-2	31700	292060	
1397+0	4:38	816	41	31700	323760	
1396+50	4:44	817	1	32000	355760	
1395+50	4:46	818	199	32140	387900	
1394+50	4:50	819	111	32040	419940	
1393+75	4:54	820	3	32000	451940	
1393+25	4:57	821	4	31640	483580	
1392+75	5:02	822	C-1	31700	515280	
1392+0	5:07	823	H-3	31600	546880	
1391+0	5:10	824	R-2	31620	578500	
1390+0	5:14	825	41	31600	610100	
1389+0	5:18	826	1	32000	642100	
1388+25	5:20	827	199	32300	674400	
1387+50	5:22	828	111	32060	706460	

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DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS
CONSTRUCTION DIVISION

Truck
Tally Sheet

Material: Bituminous Concrete

Project No. 95-7(84) City Town Benton-Palmyra Ticket Taker J. Wade Date 5/20/81

Station	Time	Slip No.	Truck No.	Net Wt.	Total Weight	Remarks
1386+75	5:25	829	3	31540	738000	
1386+0	5:27	830	4	31700	769700	
1385+0	5:39	831	C-1	31840	801540	
1384+0	5:38	832	H-3	31720	833260	
1383+0	5:42	833	R-2	31600	864860	440.3 tons
1382+25	5:45	834	41	15740	880600	4089 S.Y.
1381+75						
	SEA Binder Starts Here 403.312 30/70					
1381+75	6:05	835	1	32100	32100	
1381+0	6:10	836	199	32000	64100	
1380+0	6:15	837	111	32220	96320	
1379+0	6:20	838	3	32020	128340	
1378+25	6:25	839	4	31900	160240	
1377+75	6:30	840	C-1	31790	191980	
1376+50	6:35	841	H-3	32020	224000	
1375+75	6:40	842	R-2	31900	255900	
1375+0	6:43	843	41	31900	287800	1644 S.Y.
1374+0	6:45	844	1	31800	319600	Yield 214#/s.y.
1373+25	6:50	845	3	31800	351400	175.7 tons
1372+50						

SEA PLACEMENT DATA

Date	Direction	Lane	Mix Type	Blend	Station to Station		Tonnage
5/20/81	SB	PL	B	30/70	1381+75	1372+50	175.70
5/21/81	SB	PL	B	30/70	1372+50	1354+25	368.76
5/29/81	SB	TL	B	30/70	1388+50	1371+75	272.18
6/03/81	SB	TLS	B	30/70	1387+0	1374+10	224.80
6/03/81	SB	TL	B	30/70	1371+75	1362+0	180.25
6/04/81	SB	TL	B	30/70	1362+0	1353+0	175.84
6/04/81	SB	TLS	B	30/70	1374+10	1355+0	335.30
6/10/81	SB	TL	C	30/70	1386+75	1353+0	319.35
6/12/81	SB	TLS	C	30/70	1382+0	1350+50	258.65
6/18/81	SB	PL	C	30/70	1386+0	1353+25	416.18
6/24/81	NB	PL	B	20/80	1723+75	1788+75	1,665.66
6/25/81	SB	PL	B	10/90	1789+25	1681+80	2,388.75
6/26/81	SB	PL	B	10/90	1681+80	1604+80	1,730.27
7/07/81	NB	TL	B	20/80	1723+0	1765+80	782.78
7/08/81	SB	TL	B	10/90	1789+25	1690+50	1,847.56
7/09/81	SB	TL	B	10/90	1690+50	1605+0	1,472.33
7/09/81	NB	TL	B	20/80	1765+75	1788+95	375.65
7/10/81	NB	TLS	B	20/80	1723+0	1788+75	1,018.90
7/15/81	SB	TLS	B	10/90	1789+30	1686+75	1,566.64
7/16/81	SB	TLS	B	10/90	1686+75	1605+0	1,151.05
7/17/81	NB	TL	C	20/80	1722+10	1789+50	643.49
7/20/81	NB	TLS	C	20/80	1719+05	1789+60	985.99
7/20/81	SB	TL	C	10/90	1790+40	1722+50	628.83
7/22/81	SB	TLS	C	10/90	1790+30	1727+50	533.55
7/23/81	NB	PL	C	20/80	1725+75	1740+20	195.74
7/24/81	NB	PL	C	20/80	1740+20	1789+60	631.84
7/24/81	SB	PL	C	10/90	1790+30	1735+25	660.29
7/27/81	SB	PL	B	10/90	1605+0	1548+80	1,130.50
7/28/81	SB	PL	B	10/90	1548+80	1518+90	653.57
7/28/81	SB	PL	C	10/90	1735+25	1725+25	129.47
8/03/81	SB	TL	B	10/90	1605+0	1488+10	1,273.03
8/04/81	SB	TLS	B	20/80	1605+0	1498+10	1,646.00
							≥26,166.34

PL	Passing lane and 4' shoulder	16' wide
TL	Travel lane	12' wide
TLS	Breakdown shoulder	10' wide

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SULFUR EXTE

PROJECT	DESCRIPTION													MIX DESIGN						
	SECTION LENGTH & WIDTH (FEET)	COURSE THICKNESS (INCHES)	AGGREGATE % PASSING 1"	3/4"	3/8"	4	8	30	40	50	80	100	200	ASPHALT GRADE PEN VISC	S/A (% WT.)	BINDER CONTENT (%)	OPTIMUM DENSITY (%)	AIR VOIDS (%)	VMA (%)	MA CR ST
MAINE I-95 SB & NB Benton - Pittsfield Overlay AC Constructed August '81 Test Date August '81 ADT 9300 % Trucks 15.5	3200 24' wide	1¼ AC Surface		100	71	52	46	19	14	11	8	7	4	AC10	30/70	6.8	97.6	2.4	18.4	
		2¼ AC Binder	100	96	50	42	38	21	13	10	8	7	4	130 1100	30/70	6.2	98.0	2.0	16.4	2
	6550' 24' wide	1¼ AC Surface 2¼ AC Binder	Same as above												20/80	6.4	96.8	3.2	17.8	
															20/80	5.8	97.1	2.9	16.3	
	6570' 24' wide	1¼ AC Surface 2¼ AC Binder	Same as above												10/90	6.2	97.9	2.1	16.9	
															10/90	5.4	98.0	2.0	15.2	
	22040' 24' wide	1¼ AC Surface 2¼ AC Binder	Same as above												0/100	6.0	97.2	2.8	17.0	
															10/90	5.4	98.0	2.0	15.2	
	Control 20,000	1¼ AC Surface 2¼ AC Binder	Same as above												0/100	6.0	97.2	2.8	17.0	
															0/100	5.2	98.0	2.0	15.0	

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BEST DOCUMENT

EXTENDED ASPHALT

MIX DESIGN						CONSTRUCTION								PERFORMANCE EVALU									
R NT)	OPTIMUM DENSITY (%)	AIR VOIDS (%)	VMA (%)	MARSHAL OR HVEEM STABILITY (lbs)	MARSHAL FLOW OR HVEEM COHESION (G Cm)	PLANT (TYPE)	METHOD OF BLENDING	MIX TEMP (F°)	COMP TEMP (F°)	HYDROGEN SULFIDE (PPM)		SULFUR DIOXIDE (PPM)		EXTRACTION		FATIGUE (BEAM) (3RD PT LD)	DENSITY (PCF)	AIR VOIDS (%)	MARSHAL OR HVEEM STABILITY (lbs)	MARSHAL FLOW (G Cm)	HVEEM COHESION	INDIRECT TENSION	RICE MAX SPECIFIC GRAVITY
										PLANT	PAVER	PLANT	PAVER	BINDER CONTENT (%)	S/A (% WT)								
	97.6	2.4	18.4	1531	10	8000* Batch	Direct	275	270		2		1.25	6.7	-	-	146	4	-	-	-	-	-
	98.0	2.0	16.4	2480	11		"	285	280		2		0.75	6.0	-		150	4	-	-	-	-	-
	96.8	3.2	17.8	1758	14	"	"	278	275		2		-	6.2	-	-	148	4					
	97.1	2.9	16.3	1436	11	"	"	270	265		2		0.25	5.7	-	-	-	-					
	97.9	2.1	16.9	1800	11	"	"	275	270		2		-	6.1	-	-	145	5					
	98.0	2.0	15.2	1395	10	"	"	285	280		2		0.25	5.6	-	-	-	-					
	97.2	2.8	17.0	1840	10	"	"	280	275		-		-	5.8	-	-	147	4					
	98.0	2.0	15.2	1395	10	"	"	280	275		2		0.25	5.5	-	-	-	-					
	97.2	2.8	17.0	1840	10	"	"	280	275		-		-	5.8	-	-	147	4					
	98.0	2.0	15.0	1930	10	"	"	280	275		-		-	5.2	-	-	149	4	-	-	-	-	-

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PERFORMANCE EVALUATION

EXTRACTION		FATIGUE (BEAM) (3RD PT LD)	DENSITY (PCF)	AIR VOIDS (%)	MARSHAL OR HVEEM STABILITY (lbs.)	MARSHAL FLOW (0.01in)	HVEEM COHESION	INDIRECT TENSION	RICE MAX SPECIFIC GRAVITY	BENK-LEMEN BEAM DEFL.	RESILIENT MODULUS			MAXIMUM DYNAFLECT DEFL. (10^{-3})	STRIP-PING	SKID RESIST.	RUTTING	RAVEL-LING	CRACK-ING
BINDER CONTENT (%)	S/A (% WT)										39%	77%	100%						
6.7	-	-	146	4	-	-	-	-	-	.022	-	-	-	-	-	47	-	-	-
6.0	-		150	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6.2	-	-	148	4						.010						52			
5.7	-	-	-	-						-									
6.1	-	-	145	5						.026						49			
5.6	-	-	-	-						-									
5.8	-	-	147	4						.022						45			
5.5	-	-	-	-						-									
5.8	-	-	147	4						.022						45			
5.2	-	-	149	4	-	-	-	-	-	-									